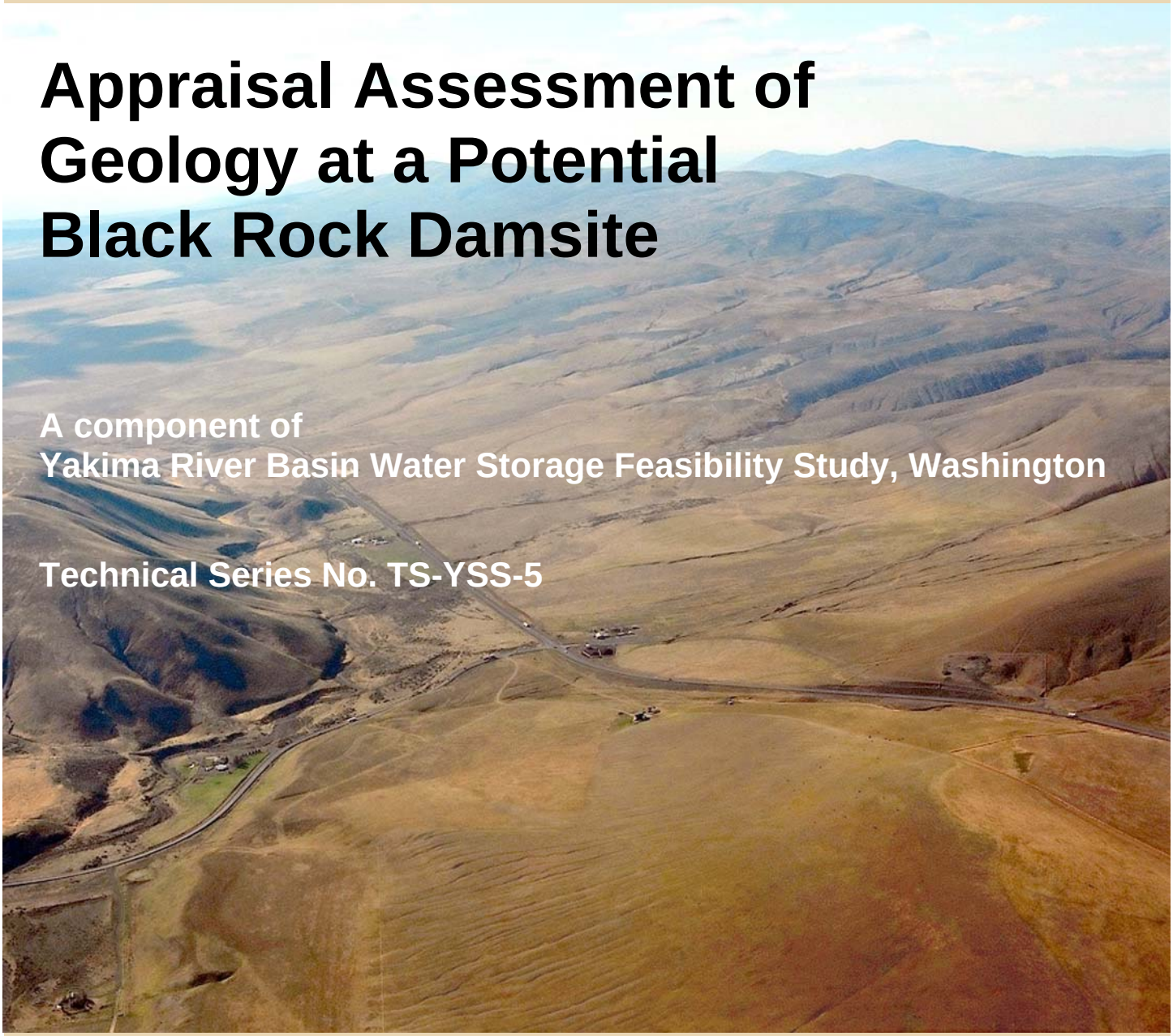
RECLAMATION

Managing Water in the West

Appraisal Assessment of Geology at a Potential Black Rock Damsite

A component of
Yakima River Basin Water Storage Feasibility Study, Washington

Technical Series No. TS-YSS-5



Black Rock Valley

U.S. Department of the Interior
Bureau of Reclamation
Pacific Northwest Region

December 2004

RECLAMATION

Managing Water in the West

Appraisal Assessment of Geology at Black Rock Damsite

A component of
Yakima River Basin Water Storage Feasibility Study, Washington

Technical Series No. TS-YSS-5

Prepared by: Donnie N. Stelma, Geologist
Under supervision of Richard A. Link, Regional Geologist

U.S. Department of the Interior
Bureau of Reclamation
Pacific Northwest Region
Regional Resource & Technical Services
Geology, Exploration & Instrumentation Group
Boise, Idaho

December 2004

U.S. Department of the Interior
Mission Statement

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

Bureau of Reclamation
Mission Statement

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Preface

Congress directed the Secretary of the Interior, acting through the Bureau of Reclamation (Reclamation), to conduct a feasibility study of options for additional water storage for the Yakima River basin. Section 214 of the Act of February 20, 2003, (Public Law 108-7) contains this authorization and includes the provision "… with emphasis on the feasibility of storage of Columbia River water in the potential Black Rock Reservoir and the benefit of additional storage to endangered and threatened fish, irrigated agriculture, and municipal water supply."

Reclamation initiated the *Yakima River Basin Water Storage Feasibility Study* (Storage Study) in May 2003. As guided by the authorization, the purpose of the Storage Study is to identify and examine the viability and acceptability of alternate projects by: (1) diversion of Columbia River water to the potential Black Rock reservoir for further water transfer to irrigation entities in the lower Yakima River basin as an exchange supply, thereby reducing irrigation demand on Yakima River water and improving Yakima Project stored water supplies, and (2) creation of additional storage within the Yakima River basin. In considering the benefits to be achieved, study objectives will be to modify Yakima Project flow management operations to most closely mimic the historic flow regime of a Yakima River system for fisheries, provide a more reliable supply for existing proratable water users, and provide additional supplies for future municipal demands.

State support for the Storage Study was provided in the 2003 Legislative session. The capital budget included a $4 million appropriation for the Department of Ecology (Ecology) with the provision the funds "… are provided solely for expenditure under a contract between the department of ecology and the United States bureau of reclamation for the development of plans, engineering, and financing reports and other preconstruction activities associated with the development of water storage projects in the Yakima river basin, consistent with the Yakima river basin water enhancement project, P.L. 103-434. The initial water storage feasibility study shall be for the Black Rock reservoir project."

Reclamation's Upper Columbia Area Office in Yakima, Washington, is managing and directing the Storage Study. Pursuant to the legislative directives, Reclamation has placed initial emphasis on Black Rock alternative study activities. These study activities are collectively referred to as the Black Rock Alternative Assessment (Assessment).

The Assessment has three primary objectives. First, it provides the emphasis directed by Federal and State legislation. Second, it builds upon prior work and studies to provide more information on the configuration and field construction cost of the primary components of a Black Rock alternative. It examines legal and institutional considerations of water supply and use, and identifies areas where further study is needed. Third, it is a step forward in identifying the viability of a Black Rock alternative.

This technical document, prepared by Reclamation's Pacific Northwest Regional Geology, Exploration & Instrumentation Group, Boise, Idaho, is one of a series of documents prepared under the Storage Study. This particular document is a component of the Assessment reporting on preliminary geologic investigations conducted in 2003 and 2004 at the alternate Black Rock damsite. Information and findings of this technical document are included in the Assessment Summary Report.

Further Consultations

The information available at this time is necessarily preliminary, has been developed only to an appraisal level of detail, and is therefore subject to change if this alternative is investigated further in the course of the Yakima River Basin Storage Feasibility Study (Storage Study). Finally, economic, financial, environmental, cultural, and social evaluations of the Black Rock alternative have not yet been conducted.

The policy of the Bureau of Reclamation (Reclamation) requires non-Federal parties to share the costs of financing feasibility studies and the eventual construction of Federal reclamation projects. In light of this policy, the preliminary cost estimates presented in the Assessment Summary Report, and current Federal budgetary constraints, Reclamation is not reaching a decision at this time as to whether the Black Rock alternative will be carried forward into the next phase of the Storage Study or dropped from further consideration. Rather, Reclamation will consult with the State of Washington (which is cost sharing in the Storage Study), the Yakama Nation, the potential water exchange participants, project proponents, and other interested parties before making a decision in this regard. It is anticipated that a decision will be reached by the fall of 2005.

If the Congress provides further funding for the Storage Study, all technically viable alternatives would be compared and an alternative(s) selected for further analyses in the feasibility phase. (Whether the Columbia River-Yakima River water exchange concept in the form of the Black Rock alternative is included will depend upon whether Reclamation, after these additional consultations, decides to carry that alternative forward into the plan formulation phase of the Storage Study.) The selected alternative(s) would then be subject to detailed evaluation in the feasibility phase in terms of engineering, economic, and environmental considerations, and cultural and social acceptability. This feasibility phase would be the last phase of the Storage Study. Preparation of the Feasibility Report/Environmental Impact Statement would be a part of this final phase.

TABLE OF CONTENTS

Page

TABLE

FIGURES

PHOTOGRAPHS

APPENDICES

Appendix A

Geologic and Geophysical Logs

Results of Geochemical Analyses

Appendix B - Drawings

SUMMARY AND CONCLUSIONS

The original Black Rock Damsite was investigated by a private engineering consulting firm in 2002 and 2003. That study suggested that a more suitable damsite may lie west of the original study area. Based on the available understanding and mapping at the time, the location further west was thought to be less complicated due primarily to the presence of a potential north-south fault thought to place the bedrock nearer the ground surface.

Bureau of Reclamation forces performed investigations at the alternate Black Rock Damsite in 2003 and 2004. These investigations included drilling holes to determine the depth to bedrock along the alternate alignment, drilling a single core hole to obtain samples of the deep foundation to determine engineering characteristics and provide a pilot hole for a ground-water test hole, and performing a reconnaissance survey for borrow materials.

Five bedrock confirmation holes were drilled at the alternate site. The holes were drilled on the lower abutments and in the channel area. The information from these holes showed that the depth to bedrock (overburden thickness) is greater at the alternate alignment than at the original damsite. Using this data, the engineer's estimate for the total embankment quantities showed that the alternate alignment would require approximately 10,000,000 cubic yards (yd^3) more than the original site. Based on these estimates it was determined the original site is best suited for the structure.

The upper foundation at the damsites is composed of Quaternary loessial and alluvial deposits underlain by sediments of the Tertiary Ringold Formation. The deep foundation bedrock is composed of volcanic rocks of the Saddle Mountain Basalt Formation of the Columbia River Basalt Group. The geologic and engineering properties of the shallow and deep foundation materials are similar at both damsites.

Three ancient landslides identified on the Horsethief Mountain ridge are located near the south (right) abutment at the original damsite; two landslides are upstream from the damsite, one of which is on the north slope and the other is in the reservoir basin; the third is downstream from the damsite.

Construction materials for the dam and associated structures can be obtained from both developed and undeveloped land within approximately 35 miles of the site. Geologically, the sources consist of recent Yakima and Columbia River alluvium, post-Yakima Fold Belt alluvium, and Columbia River basalt.

Nineteen potential borrow material sites were identified during the reconnaissance survey. The main material types for the dam include impervious fill, rockfill, processed material for filter and drain elements, and concrete aggregate and sand.

It is common practice to obtain material from the reservoir basin during construction of large embankment dams. The Black Rock Valley and possibly Dry Creek Valley, south of the damsite, are potential sources for zoned earthfill for the embankment. Mining in the Black Rock Valley would have to be performed in a manner that would not compromise the water-holding ability of the reservoir basin or increase seepage in the vicinity of the dam. The likely area would be at the upper end of the valley, furthest from the damsite where reservoir depth is minimal.

In order to meet gradation requirements for filter, drain, and concrete aggregate, washing and screening of raw material will be necessary. The nearest sources of relatively clean material include Columbia River or Yakima River alluvial deposits, where well-sorted sand and gravel with minimal fines and wash water for processing are readily available.

INTRODUCTION

Section 214 of the Act of February 20, 2003, Public Law 108-7, authorized the U.S. Department of the Interior, Bureau of Reclamation (Reclamation) to conduct a feasibility study of options for additional water storage in the Yakima River Basin with emphasis on the feasibility of storage of Columbia River water in the potential Black Rock Reservoir.

The Yakima River Basin Water Enhancement Project feasibility study conducted in the 1980's included possible storage by enlarging an existing reservoir or constructing an offstream reservoir within the Yakima River Basin. More recently Washington Infrastructures Services, Inc. (WIS) investigated the Black Rock Damsite in December 2002 and prepared a final report entitled, *Black Rock Reservoir Study, Initial Geotechnical Investigation*, dated January 2003 (Washington Infrastructure Services, Inc., 2003). WIS completed the study for Benton County, Washington, which addressed pumping water from the Columbia River for storage in a proposed Black Rock Reservoir. This water would then be made available for irrigation, instream flow enhancement, and municipal purposes in the Yakima River Basin. Water would be delivered to the Roza and/or the Sunnyside Canals in exchange for part or all of their Yakima River Basin water supply. The exchanged water could then be used for instream flow enhancement and/or for irrigation in dry years.

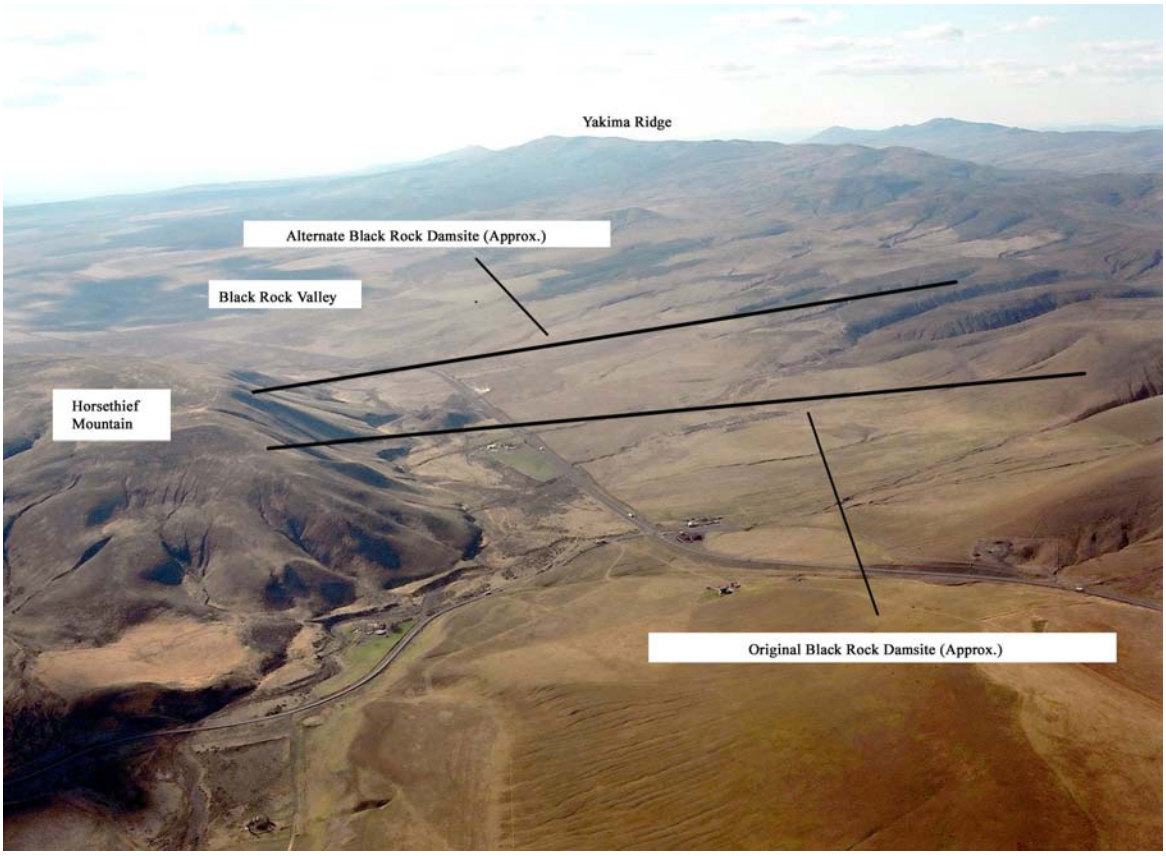
Purpose

WIS completed field investigations of the original dam site in December 2002. The WIS report states that a north-south trending discontinuity (fault) may exist across the valley just west of the original alignment. The report suggested investigating an alternate alignment located about one-half mile west of the original site (refer to Photograph 1). The investigations were intended to determine if the offset along the postulated fault places foundation bedrock nearer the ground surface, which would reduce overburden thickness and project costs.

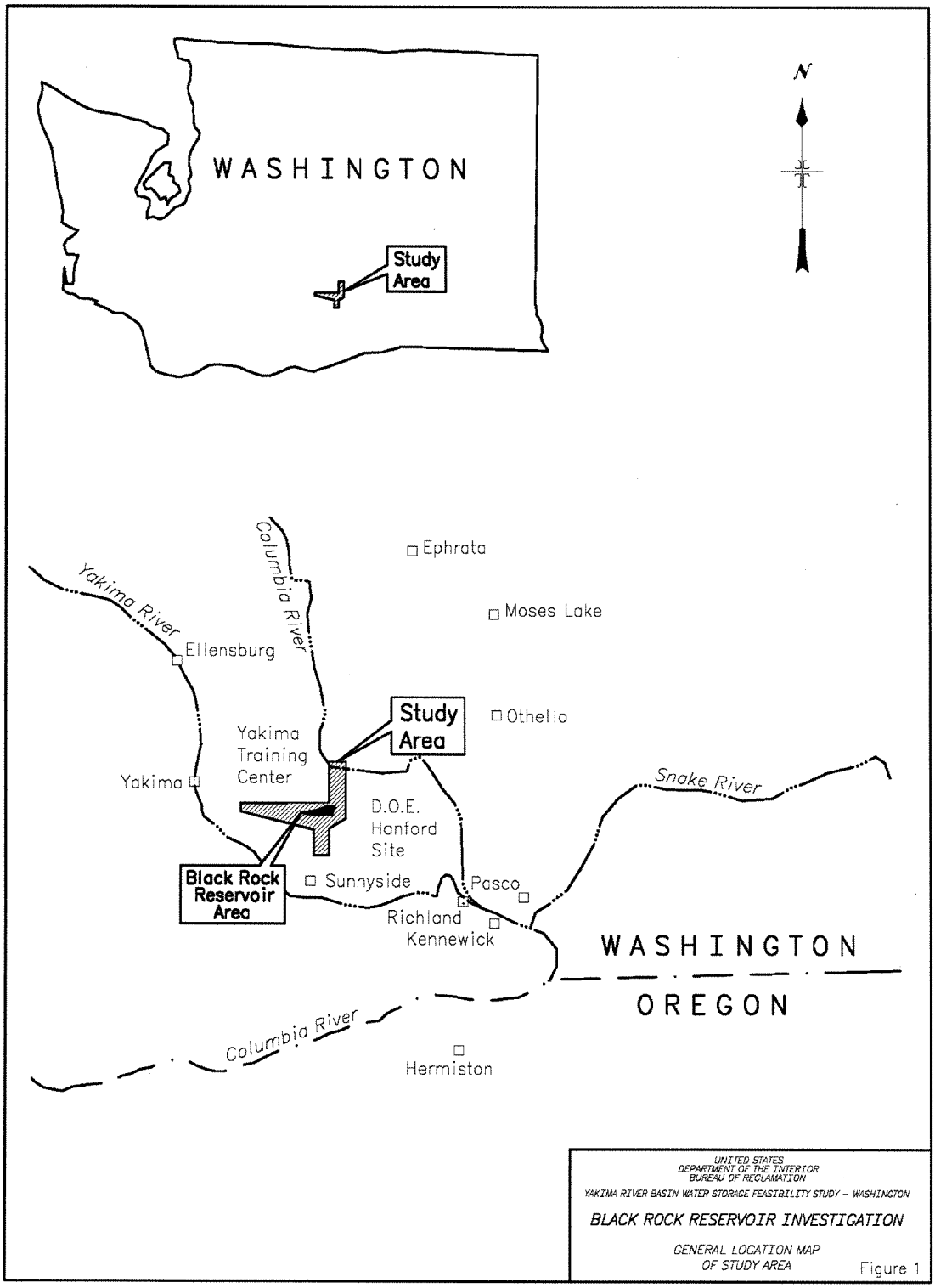
This report summarizes the findings of the exploratory drilling program conducted at the alternate Black Rock Damsite. The data collected were used to assess the suitability of the foundation at the alternate site for the proposed embankment. The field program involved drilling along the alternate alignment to confirm the depth to bedrock and determine if a north-south structural discontinuity exists between the two dam sites. In addition to the drilling program, a reconnaissance-level borrow material investigation was conducted.

Location

The Black Rock Damsites are located in the Black Rock Valley about 24 miles east of Yakima, Washington via State Highway 24 through the Moxee Valley (refer to Figure 1). The original Black Rock Damsite is located in Section 12 and the N1/2 of Section 13, T.12 N., R. 23 E. The alternate Black Rock Damsite is located in the N1/2 of Section 14, Section 11, and the S1/2 of Section 2, T.12 N., R. 23 E.



Photograph 1. View looking west at Black Rock Valley and the approximate location of the damsites. Horsethief Mountain forms the south (right) abutment and the Yakima ridge the north (left) abutment. Black Rock Damsite, Yakima River Basin Water Storage Feasibility Study, Washington - Bureau of Reclamation photograph taken by D.M. Walsh, June 17, 2003.


WASHINGTON
Study Area
N
Ephrata
Moses Lake
Columbia River
Yakima River
Ellensburg
Study Area
Othello
Yakima Training Center
Yakima
Snake River
D.O.E. Hanford Site
Black Rock Reservoir Area
Sunnyside
Pasco
Richland
Kennewick
WASHINGTON
OREGON
Columbia River
Hermiston
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA RIVER BASIN WATER STORAGE FEASIBILITY STUDY - WASHINGTON
BLACK ROCK RESERVOIR INVESTIGATION
GENERAL LOCATION MAP
OF STUDY AREA
Figure 1

Previous Investigations

WIS investigated the Black Rock Damsite in December 2002 and prepared a final report in 2003. This investigation was funded by Benton County through a grant from the State of Washington. The investigation program consisted of conducting geologic mapping and completing five test borings, nine test pits, water pressure testing, and a geophysical refraction survey. Two important conclusions were drawn from this investigation. First, the depth to bedrock in the main section of the damsite was considerably deeper than the 25 feet initially estimated, reaching depths as great as 216 feet in the maximum section. Also, the basaltic lava flows that form the bedrock at the site were considerably more fractured and broken than originally thought and rock quality was generally low. None of the borings intercepted the water table, and no observation wells were installed at the site.

Current Investigation

The current investigations included development of topographic base maps of the entire study area, and drilling exploratory holes and geologic mapping at the alternate dam alignment.

Topographic Base Map

The mapping work included surveying for a control network, placing temporary photographic panels, and completing aerial photography, scanning, photogrammetric mapping to produce a digital elevation model of the area. The digital elevational model was used to develop 2-foot contour topographic base maps of the Columbia River intake area, Black Rock reservoir site, Black Rock outlet area, and most areas in between. Existing USGS 7.5-minute quadrangle maps with 20-foot contour intervals provided topographic information for locations outside the coverage area, including a small portion of the outflow conveyance system between Black Rock Reservoir and Roza Canal and the Roza and Sunnyside delivery systems.

Exploratory Drilling and Geologic Mapping

Drilling, sampling, and testing were performed to determine the depth to bedrock and characterize the bedrock at the alternate Black Rock Damsite. Drilling was performed by Reclamation drill crews. Equipment included an Ingersoll-Rand A-220 truck-mounted rotary drill and a Gus Pech truck-mounted rotary drill, with standard support equipment including air compressors and circulating pumps. The top of bedrock confirmation holes (drill holes DH-03-1 through DH-03-5) were drilled using a 6-inch ODEX casing advancer system. Core samples of the bedrock were obtained, when possible, to verify the bedrock surface using HQ wire-line [2.5-inch inner diameter (I.D.)] coring systems with clear water as circulating fluid.

Two deep foundation borings were drilled. Drill Hole DH-04-1 was cored in order to define the deep foundation and DH-04-2 was cored to perform hydrogeology analysis. Both deep holes were drilled using an Ingersoll-Rand T-2 truck-mounted rotary drill with standard support equipment including air compressors and circulating pumps.

Coring was performed using a wire-line coring system with a polymer and water mixture used for circulating fluid. The upper part of the deep hole was advanced with PQ wire line (3.3-inch I.D.) and steel surface casing was later installed to stabilize the hole and enhance fluid return. The lower part of the hole was drilled using an HQ wire-line system with polymer and water as circulating fluid. Water for drilling was procured from a privately-owned water well located about 3 miles from the site.

The hydraulic conductivity test hole, DH-04-2, was drilled with standard rockbit and downhole hammers systems using a combination of air, water, and foam to remove the cuttings. Various water tests were conducted as the hole was drilled. Results are presented in the report entitled, *Appraisal Assessment of Hydrogeology at Black Rock Damsite, Technical Series No. TS-YSS-6* (Bureau of Reclamation, 2004b).

Borehole geophysical testing was conducted in six of the seven drill holes. Geophysics included natural gamma (clay content and lithology), neutron (water content), and gamma-gamma (density), along with deviation and directional surveys. Color plots of the borehole geophysical data are included with geologic logs located in Appendix A.

Samples were tested in the field to determine magnetic polarity of the basaltic flows using a fluxgate magnetometer. The magnetic polarity was used to verify the general stratigraphic sequence of the basaltic formations encountered during drilling. In addition, core samples were submitted to the Washington State University GeoAnalytical Laboratory, Pullman, Washington, for geochemical analysis. Magnetic polarity results are shown on geologic logs and the geochemical analyses data and results are included in Appendix A. Dr. Robert D. Bentley, professor emeritus at Central Washington University, Ellensburg, Washington, provided valuable assistance in field tests and data analysis.

A report prepared under contract by Columbia Geotechnical Associates, Inc. gives an overview of the geology at the alternate damsite. The geologic mapping extended from the WIS Study to include the Black Rock Alternate Damsite. Results are presented in the February 2004 report (Lenz, Walls, and Bentley, 2004)

REGIONAL GEOLOGY

The Black Rock Dam and Reservoir sites are located in the northwest-central portion of the Columbia Basin, a structural and depositional basin that forms much of eastern Washington (Washington Infrastructure Services, Inc., 2003). The basin is the site of large basaltic flood lava known as the Columbia River Basalt Province. The basalts were erupted between 18 and 6 million years ago from vents near the present boundary between Washington, Oregon, and Idaho. Flows were up to 100 feet thick and covered hundreds to thousands of square miles. Extended time periods between eruptions allowed for the sediment deposition. Sediments consisted primarily of lacustrine silt and fluvial sand and gravel from the ancestral Columbia River and its tributaries. Basaltic eruptions over millions of years resulted in a stack of relatively horizontal flows that are referred to as the Columbia Plateau.

The western portion of the Columbia Plateau underwent north-south directed compression resulting in faulting and generally east-west trending folds. The folds are referred to as the Yakima Fold Belt. The ridges of the Yakima Fold Belt are generally asymmetrical, with one limb gently inclined while the other is steeply folded, often with a thrust fault near the base of the fold. Most of the structural relief, the Elephant Mountain Basalt of the Saddle Mountains Formation, has developed since 10.5 Ma, when the last massive outpouring of lava buried much of the central Columbia Basin (Reidel, Martin, and Petcovic, 2003). The anticlines represent the ridges and the synclines represent the valleys. This configuration exists at the Black Rock Damsites, which are sited between the Yakima Ridge anticline on the north and Horsethief Mountain/Rattlesnake Hills anticline on the south (refer to Figure 2).

Seismicity

A Preliminary Seismic Hazard Assessment was conducted by Reclamation to determine the seismic hazard at the Black Rock Damsite. Seismic loadings at the site are significant and for this study the thrust faults associated with individual folds within the Yakima Fold Belt have been considered as potential earthquake sources (Bureau of Reclamation, 2004c). Some potential exists for surface faulting associated with the Horsethief Mountain Thrust Fault in the right abutment and along the south edge of the reservoir (refer to Drawing 33-100-3381; all drawings are located in Appendix B).

Reclamation typically designs its power and pumping facilities for earthquakes having a return period of 2,500 years, and dams for earthquakes having return period of 10,000 years. For the damsite area, an earthquake having return period of 2,500 years has an estimated total Peak Horizontal Acceleration (PHA) of about 0.50g and at a return period of 10,000 years, the total PHA is about 0.95g (Bureau of Reclamation, 2004c).

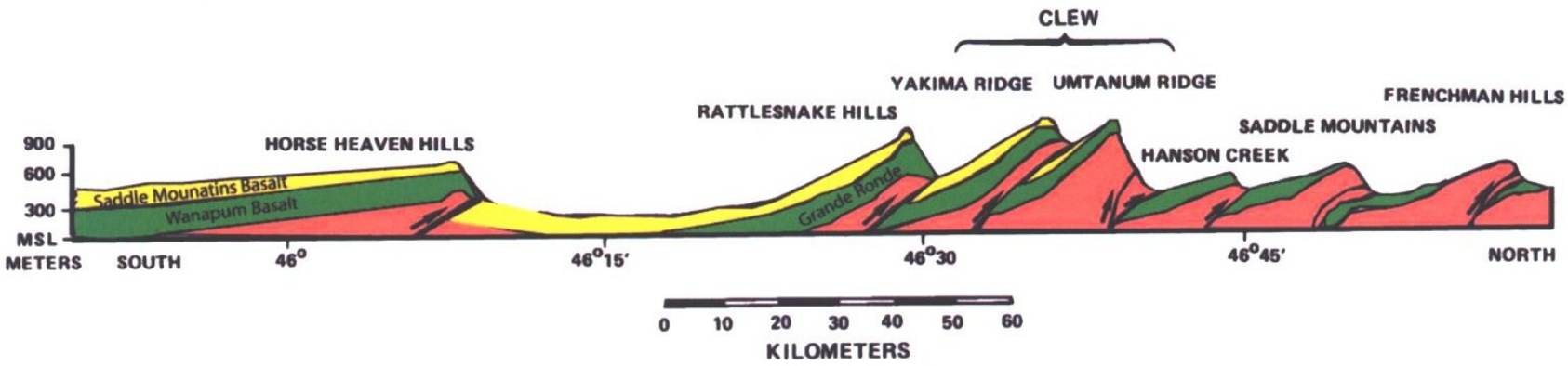


Figure 2. Generalized cross section through the Yakima Fold Belt (from Reidel and Campbell, 2003). The Black Rock Damsite is located between the Rattlesnake Hills and Yakima Ridge.

SITE GEOLOGY

Geologically, the foundation conditions at the two damsites are similar based on a comparison of material encountered in drill holes DH-1, DH-2, DH-3, DH-4, and DH-6 at the original site and drill holes DH-03-1 through -5 and DH-04-1 at the alternate site (refer to Drawing 33-100-3381). The sites are underlain by an interbedded sequence of volcanic and sedimentary rocks of the Columbia River Basalt Group and late Pliocene- to Holocene-age fluvial, lacustrine, and wind-blown deposits. The upper foundation is composed of Quaternary loessial and alluvial deposits underlain by sedimentary Tertiary Ringold Formation. The deep foundation bedrock is composed of volcanic rocks of the Saddle Mountain Basalt and upper Wanapum Formations of the Columbia River Basalt Group.

The geology and stratigraphy described here is based on exploratory drilling performed at the alternate Black Rock Damsite, and from interpretations of foundation geology presented in reports by Lenz, Walls, and Bentley (2004) and Washington Infrastructure Services, Inc. (2003). The alluvial units documented from drilling at the alternate Black Rock Damsite include wind-blown loess (Qe) and alluvial (Qh) deposits. These are underlain by the Tertiary Ringold Formation (Tr), which consists of fine- to coarse-grained sediments deposited within the Yakima Fold Belt. The underlying Columbia River Basalt Group consists of the Saddle Mountains Basalt Formation, which includes the Elephant Mountain Basalt Member (Tem), Pomona Basalt Member (Tp), and Esquatzel and Umatilla Basalt Members (Teq/Tum). The long periods between eruptions allowed for the deposition of sediments between flows. These sediments include sand and gravel bar deposits from the Columbia River, and finer-grained silt and clay layers deposited in shallow lake formed by temporary damming of the Columbia River. The sediments are known as the Ellensburg Formation and include the Rattlesnake Ridge Interbed (Trr), Selah Sedimentary Interbed (Ts), and the Mabton Sedimentary Interbed (Tm). At depth, the upper Priest Rapids Basalt Member (Tpr) of the Wanapum Basalt Formation was encountered. The main geologic units encountered at the alternate site are shown on the generalized stratigraphic section (refer to Figure 3) and are described in the flowing sections from youngest (recent) to oldest.

Quaternary Loessial Deposits (Qe)

Deposits of Holocene-age wind-blown loess blanket the site. The loess consists primarily of brown, dry to moist, fine sand, and nonplastic silt. The loess was encountered in test borings at both damsites (refer to Drawing Nos. 33-100-3382 through -3384).

Quaternary Alluvial Deposits (Qh)

The alluvial deposits consist of undifferentiated coarse- to medium-grained sand with fines, gravel, cobbles, and boulders composed of basaltic detritus from local sources. The alluvium was encountered in test borings DH-03-1, DH-03-2, DH-03-3, DH-03-4, DH-03-5, and DH-04-1, and was differentiated from the underlying Ringold Formation at the alternate damsite based primarily on the coarse-grained nature of the unit (refer to Drawing No. 33-100-3383).

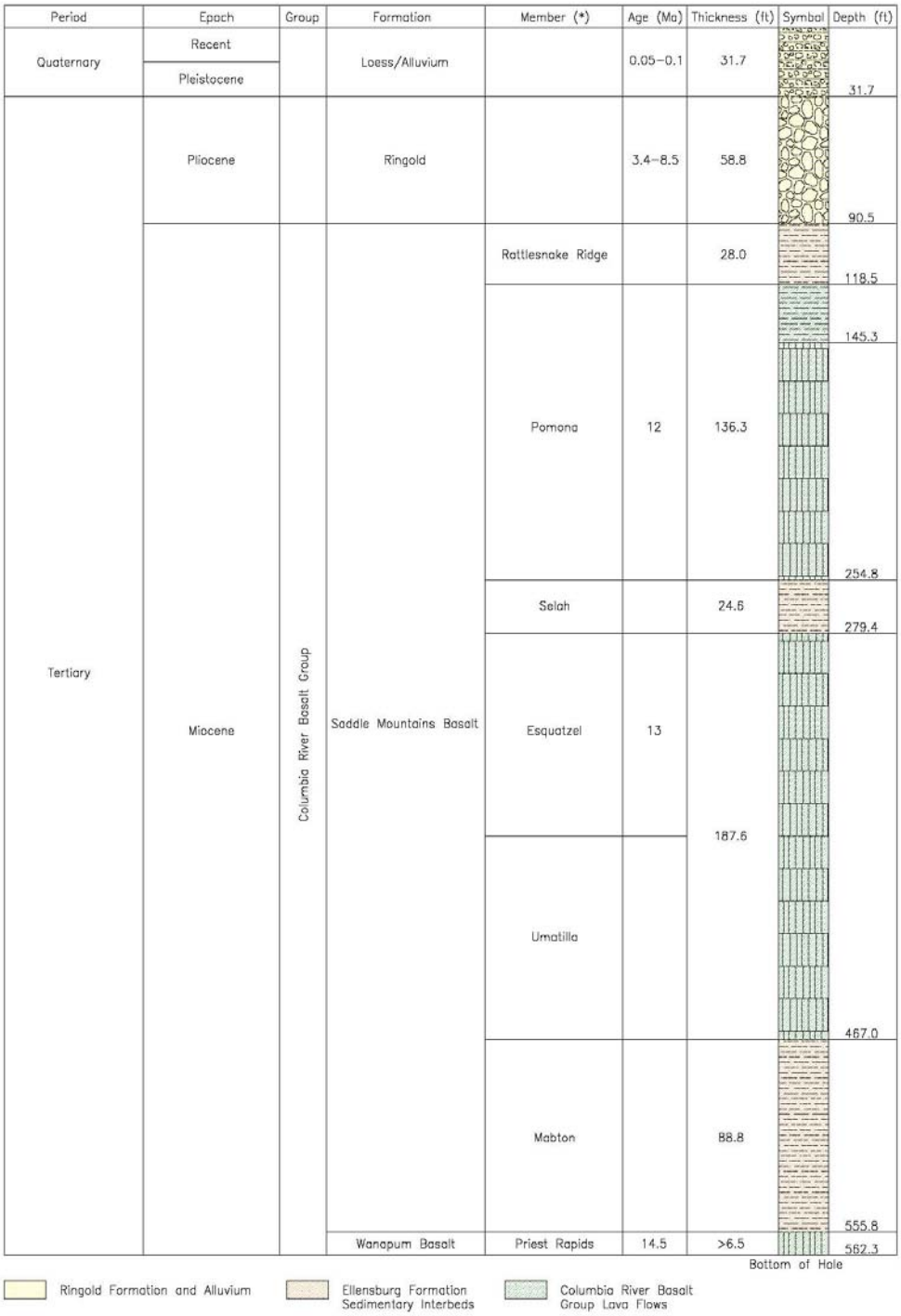


Figure 3. Generalized stratigraphic section of the alternate Black Rock Damsite based on drill hole DH-04-1 (adapted from Lenz, Wells, and Bentley, 2004; Washington Infrastructure Services, Inc., 2003; and Reidel and Campbell, 2003).

Ringold Formation (Tr)

The Ringold Formation is distinguished from the overlying alluvium based on a change from predominantly coarse-grained material to predominantly fine-grained material. The unit can be divided into three roughly equal sections. The upper and lower sections are coarser-grained fluvial deposits with material ranging from poorly- to well-indurated sand and fines, to gravel and fines with cobbles. The base of the Ringold Formation is characterized by a 10-foot-thick layer of cobbles. The middle of the formation is finer-grained, consisting of well-indurated clayey sand with gravel. The material is expected to be a firm foundation capable of supporting a large dam, although a seepage cutoff to bedrock may be necessary. The Ringold Formation was encountered in test borings at both damsites (refer to Drawing Nos. 33-100-3382 through -3384).

Elephant Mountain Basalt (Tem)

The Elephant Mountain Basalt is the uppermost basaltic flow in the Saddle Mountains Basalt Formation. The Elephant Mountain Member was not encountered in the deep holes (DH-03-1 or DH-04-1) at the alternate damsite and may have been removed by erosion, but was encountered in a single hole (DH-2) at the original damsite (refer to Drawing No. 33-100-3382). The unit is a single, thin flow that consists of black, medium-grained basalt with small olivine phenocrysts (Washington Infrastructure Services, Inc., 2003).

Rattlesnake Ridge Interbed (Trr)

The Rattlesnake Ridge Interbed is a member of the Ellensburg Formation and includes the sedimentary deposits between the Ringold Formation and the Pomona Basalt Member. The unit is composed of fluvial gravel, sand, and cobbles with intensely weathered basaltic fragments and tuffaceous silt and clay. The unit represents sedimentary deposition of channel and floodplain materials in conjunction with eruption of Columbia River basalts. The Rattlesnake Ridge Interbed was encountered in test borings at both damsites (refer to Drawing Nos. 33-100-3382 through -3384).

Pomona Basalt Basalt (Tp)

The Pomona Basalt underlies the Black Rock Valley and forms the foundation bedrock at the alternate damsite. The basalt has reverse magnetic polarity and contains fine plagioclase crystals as indicated in hand samples. The Pomona flow is invasive into the underlying Selah interbed and includes an upper thin contact zone of rafted sediments containing glassy vesicular basalt with inclusions of fine sediment. The altered sediments are referred to as a peperite due the textural characteristic of white tuffaceous sediments with scattered fragments of black basalt. The lower portion of the flow is slightly weathered, hard, intensely to moderately fractured basalt (refer to Photograph 2). The Pomona Basalt was encountered in test borings at both damsites (refer to Drawing Nos. 33-100-3382 through -3384).

Photograph 2. View of Pomona Basalt core sample prior to removal from inner core barrel. The rock is slightly weathered, hard, and intensely to moderately fractured with tight to slightly open joints. The sample is from drill hole DH-04-1 from 191.4 to 210.4 feet. Black Rock Damsite, Yakima River Basin Water Storage Feasibility Study, Washington – Bureau of Reclamation photograph taken by D.N. Stelma, February 24, 2004.

Selah Sedimentary Interbed (Ts)

The Selah Interbed is a member of the Ellensburg Formation and includes the sedimentary deposits between the Pomona and Esquatzel Members and Umatilla Basalt Member. The unit is composed mostly of tuffaceous siltstone and claystone consisting of reddish-orange to black, well-indurated clay to medium sand-sized lithic fragments of pumice, ash, and chert (refer to Photograph 3). The Selah Interbed represents deposition by the Columbia River and other streams between intense periods of volcanism. Additionally, the upper contact of the Pomona Member is interpreted to be an invasive flow, which is Selah Interbed sediments rafted to the flow surface during emplacement of the Pomona Basalt. The Selah Interbed was encountered in test boring DH-04-1 at the alternate damsite (refer to Drawing Nos. 33-100-3383 and -3384).

Undifferentiated Esquatzel and Umatilla Basalt (Teq/Tum)

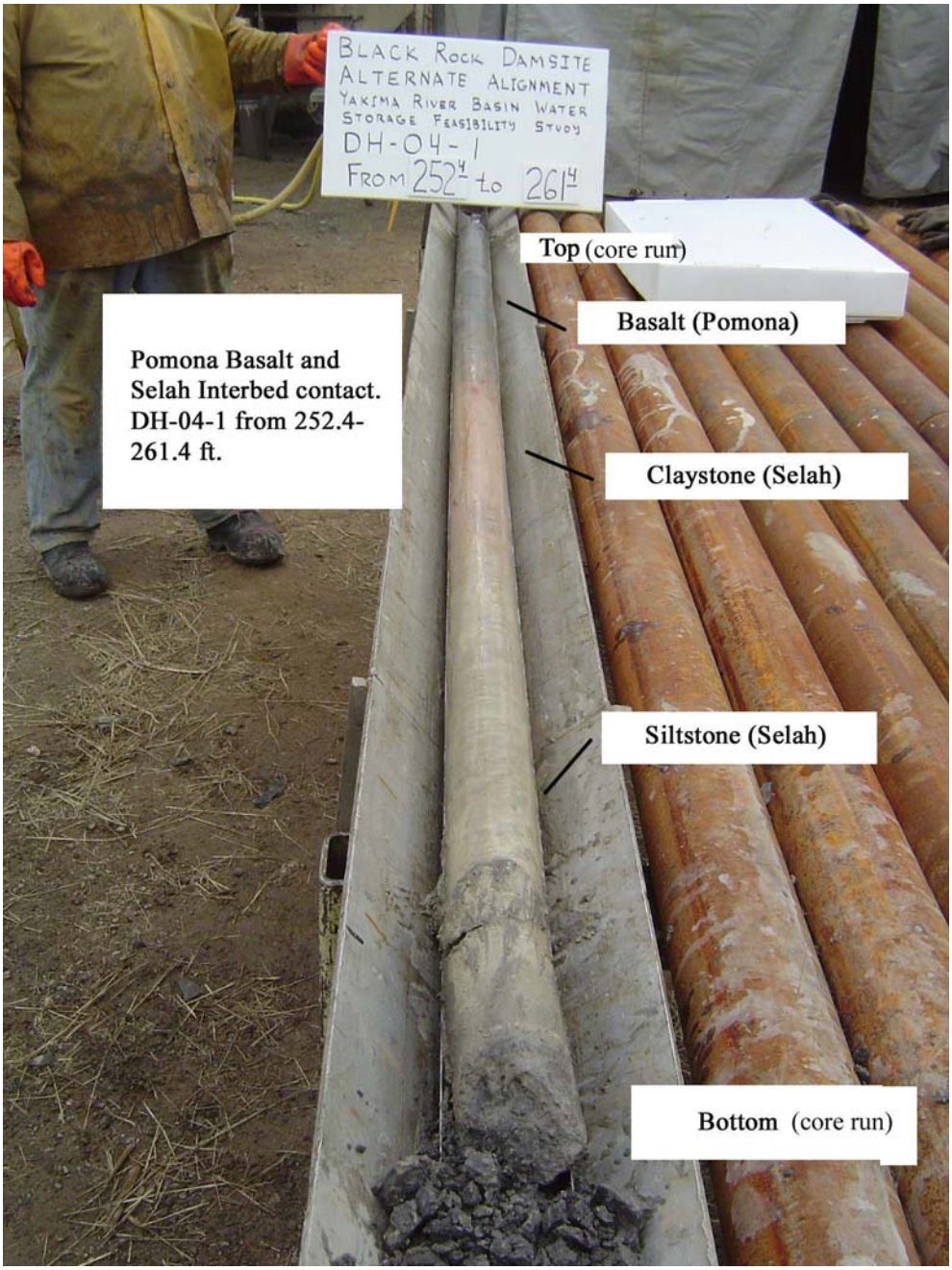
The Esquatzel Member is an intercanyon flow that filled ancestral Columbia River channels, sometimes overflowing the channel and pouring out into the floodplain (Washington Infrastructure Services, Inc., 2003). The Esquatzel Basalt overlies the Umatilla Basalt and it is impossible to visually distinguish between the two flows in hand samples. Both flows have normal magnetic polarity. Due to similar characteristics the members are addressed as a single unit on the geologic logs and in this report. The flows consist of gray to dark gray, hard, dense to slightly vesicular, fine-grained basalt that is slightly weathered. The units were encountered in test boring DH-04-1 at the alternate damsite (refer to Drawing Nos. 33-100-3383 and -3384).

Mabton Sedimentary Interbed (Tm)

The Mabton Sedimentary Interbed is member of the Ellensburg Formation and includes the sedimentary deposits between the Saddle Mountains and Wanapum Basalt Formations. The units consists of a thick sequence of tuffaceous siltstone, sandstone, and claystone that represents an extended time period of deposition between eruptions. The Mabton Interbed was encountered in test boring DH-04-1 (refer to Drawing Nos. 33-100-3383 and -3384).

Priest Rapids Basalt (Tpr)

The Priest Rapids Basalt is a member of the Wanapum Basalt Formation and is distinguished by stratigraphic position, and its coarse-grained texture and reverse magnetic polarity. It may be present near the top of the dam on the south abutment, near the hinge of a fold, and is expected to be fractured based on its location next to this structure (Washington Infrastructure Services, Inc., 2003). The Priest Rapids Basalt was encountered at depth in drill hole DH-04-1. Drilling was stopped after penetrating only 6.5 feet into the flow (refer to Drawing Nos. 33-100-3383 and -3384). Its total thickness at the site is unknown.



Photograph 3. View of core sample showing the contact between the Pomona Basalt (Saddle Mountains Basalt Formation) and the underlying Selah Interbed (Ellensburg Formation) prior to removal from coring tube. Note the reddish alteration zone at the contact. The sample is from drill hole DH-04-1 from 252.4 to 261.4 feet. Black Rock Damsite, Yakima River Basin Water Storage Feasibility Study, Washington – Bureau of Reclamation photograph taken by D.N. Stelma, February 27, 2004.

ENGINEERING GEOLOGY

Two potential Black Rock Dam alignments were explored during previous and current geologic investigations. Geologic conditions at the original alignment are presented in the report entitled, *Black Rock Reservoir Study, Initial Geotechnical Investigation* (Washington Infrastructure Services, Inc., 2003). The following sections discuss explorations conducted at the alternate alignment. The primary goal was to determine whether the bedrock surface was shallower at the alternate alignment than at the original alignment. Five holes were drilled to determine the elevation of the bedrock and a single deep core hole was drilled to obtain samples of the subsurface materials and provide a pilot sample hole for hydraulic conductivity testing. Groundwater conditions at the damsite are presented in *Appraisal Assessment of Hydrogeology at Black Rock Damsite, Technical Series No. TS-YSS-6* (Bureau of Reclamation, 2004b). The holes at the alternate damsite are located on the lower right abutment, in the channel section near the middle of the valley, and on the lower left abutment (refer to Drawing 33-100-3381).

The bedrock confirmation holes were drilled using a down-the-hole-hammer and compressed air. The contact was identified by sampling drill cuttings. Once the bedrock surface was reached, a short core run was taken to confirm and obtain a sample of the rock. The deep core drill hole was drilled using standard wire-line coring equipment. Drill holes DH-03-1 through DH-03-5 were abandoned in accordance with State of Washington requirements (backfilled with bentonite). A single slotted-pipe piezometer was installed in drill hole DH-04-1. For details refer to the geologic logs of drill holes DH-03-1 through DH-03-5, DH-04-01, and DH-04-2, all located in Appendix A. Also included in Appendix A is a tabular summary of samples for geochemical testing from drill holes DH-03-2, DH-03-3, DH-03-5, and DH-04-1. A tabulation of the results of the geochemical testing is also included.

Bedrock Surface Drill Holes

Due to the limitations of the drilling equipment, the bedrock surface was only encountered in three of the six holes drilled. However, based on the limited data, and a general understanding of the structural geology, the bedrock surface was defined sufficiently for engineers to estimate overburden volumes.

Drill Hole DH-03-1

Exploration drill hole DH-03-1 was located about 230 feet north of Washington State Highway 24, near the middle of the valley at the maximum section of the alternate dam alignment (refer to Drawing 33-100-3381). The hole was advanced to a total depth of 169.6 feet. Bedrock was encountered at about 146.9 feet (elevation 1201.8 feet). The upper 7.0 feet were loess (Qe), consisting of loose, dry, brown to tan, fine sand and nonplastic silt. From 7.0 to 30 feet the foundation was composed of alluvium (Qh). Samples were not obtained, but based on drilling and cuttings returned, the material was classified as coarse- to medium-grained sand with fines, gravel, cobbles, and occasional boulders. The Ringold Formation (Tr) underlies the alluvium. Based on drilling and cuttings returned, the material appeared to be mostly sand and fines, with

some gravel and scattered cobble- and boulder-sized material. The Rattlesnake Ridge Member and the invasive Pomona flow top were sampled in DH-03-1, but based on information from companion hole DH-04-1, the units are likely present between approximately 90.0 and 146.9 feet. The bedrock encountered was part of the Pomona Basalt Member. Core samples taken consisted of black to gray, fine-grained, hard (H3), dense basalt. The core was slightly weathered (W3) with oxidation limited to fracture surfaces. The core was intensely fractured (FD7) and samples recovered ranged from fragments to 0.4 feet in length, with most of the core around 0.33 feet. The fracture surfaces were mostly subhorizontal with smooth and planar surfaces. The rock quality designation (RQD) for the core run from 165.0 to 169.6 feet (bottom of hole) was 26 percent.

The drillers' attempted to install a four-inch diameter PVC pipe for borehole geophysical surveys. However, as the steel casing was being extruded it became lodged and broke off in the in the hole. The geophysical survey was unsuccessful in the steel-cased hole. The hole was abandoned by backfilling the steel casing with cement grout.

Drill Hole DH-03-2

Exploration drill hole DH-03-2 was located approximately 806 feet south of Washington State Highway 24, west of Horsethief Point, and north of dry Black Rock Creek near the base of Horsethief Mountain west of the alternate dam alignment (refer to Drawing 33-100-3381). The hole was advanced to a total depth of 73.9 feet. The upper 3.5 feet were loess (Qe) deposits, consisting of loose, dry, brown to tan, fine sand, and nonplastic silt. From 3.5 to 28.0 feet, the foundation was composed of alluvium (Qh). Samples were not obtained, but, based on drilling and cuttings returned, the material was classified as medium- to coarse-grained sand with fines, gravel, cobbles, and occasional boulders. Underlying the alluvium is the Ringold Formation (Tr). Based on drilling and cuttings returned from 28.0 to 57.0 feet, the formation was fluivolacustrine in origin and was composed primarily of sand and gravel in a fine-grained matrix of silt and clay. The fines frequently plugged the compressed air portals at the drill bit and the down-hole casing hammer had to be retrieved several times to unplug the bit. A landslide block was encountered from 57.0 to 73.9 feet. Initially it was interpreted as bedrock, but subsequent information from drill holes DH-04-1, DH-03-4, and DH-03-5 showed that the rock encountered was probably too shallow to represent bedrock. The block rock appears to be composed of Pomona Basalt and likely represents a buried slide block that originated from the steep north limb of the Horsethief Mountain anticline, similar to Horsethief Point (refer to Geologic Section C-C', Drawing 33-100-3384). Core samples taken consisted of black to gray, fine-grained to slightly porphyritic (<5% phenocrysts), hard (H3), dense basalt. The core was slightly weathered (W3) with oxidation limited to fracture surfaces. The core was intensely fractured (FD7) and samples recovered ranged from fragments to 0.4 feet in length, but most of the core was less than 0.33 feet in length. The fracture dip angles were mostly horizontal with some subhorizontal joints. The joint surfaces were mostly smooth and planar. The orientation of the block was not evident from the fracture orientations. The RQD from 66.3 to 69.8 feet was 0 percent and from 69.8 to 73.9 feet (bottom of hole), the RQD was 12 percent.

A four-inch diameter PVC pipe was installed (grouted) for borehole geophysical surveys. Geophysics included natural gamma (clay content and lithology), neutron (water content), and gamma-gamma (density), along with deviation and directional surveys. Color plots of the borehole geophysical data are included with the respective drill log and are located in Appendix A. After the logging was completed, the hole was abandoned by backfilling with cement grout.

Drill Hole DH-03-3

Exploration drill hole DH-03-3 was located approximately 2,800 feet north of Washington State Highway 24, on the lower slope of the Yakima Ridge at the lower left abutment of the alternate dam centerline (refer to Drawing 33-100-3381). The hole was advanced to a total depth of 99.0 feet. The upper 3.0 feet were loess (Qe) consisting of loose, dry, brown to tan, fine sand, and nonplastic silt. From 3.0 to 34.0 feet the foundation was composed of alluvium (Qh). Samples were not obtained, but based on drilling and cuttings returned the material was classified as medium- to coarse-grained sand with fines, gravel, cobbles, and occasional boulders. Underlying the alluvium is the Ringold Formation (Tr). Based on drilling and cuttings returned, the formation from 34.0 to 87.0 feet was composed primarily of sand and gravel in a fine-grained matrix of silt. Geochemical test data indicate that the Elephant Mountain Basalt may be present based on a sample from 97.5 feet; refer to the summary of samples for geochemical testing in Appendix A. The geochemical test results were not conclusive. However, based on elevations and comparison with the other drill holes, the bedrock encountered is likely part of the Pomona Basalt. Core samples taken consisted of black to gray, fine-grained, hard (H3), dense basalt. The core was slightly weathered (W3) with oxidation limited to fracture surfaces. The core was very intensely to intensely fractured (FD8). Samples recovered ranged from fragments to 0.2 feet in length, but most of the core was less than 0.1 feet in length. The fracture surfaces were mostly horizontal with rough and irregular surfaces. The RQD from 96.0 to 98.5 feet was 0 percent.

A four-inch diameter PVC pipe was installed for borehole geophysical surveys. A four-inch diameter PVC pipe was installed (grouted) for borehole geophysical surveys. Geophysics included natural gamma (clay content and lithology), neutron (water content) and gamma-gamma (density), along with deviation and directional surveys. Color plots of the borehole geophysical data are included with the respective drill log and are located in Appendix A. After the logging was completed, the hole was abandoned by backfilling with cement grout.

Drill Hole DH-03-4

Exploration drill hole DH-03-4 was located approximately 350 feet south of Washington State Highway 24, near the middle of the valley at what would be the maximum section of the dam (refer to Drawing 33-100-3381). The hole was advanced to a total depth of 105.5 feet. The upper 8.0 feet were loess (Qe) consisting of loose, dry, brown to tan, fine sand and nonplastic silt. From 8.0 to 50.0 feet, the foundation was composed of alluvium (Qh). Samples were not obtained, but, based on drilling and cuttings returned, the material was designated as medium- to coarse-grained sand with fines, gravel, cobbles, and occasional boulders. Underlying the alluvium is the Ringold Formation (Tr). Based on drilling and cuttings returned, the formation

from 50.0 to 105.5 feet (bottom of hole) was composed of sand and fines, with some gravel and scattered cobble- and boulder-sized material. The drill hole was terminated at 105.5 feet due to the limits of the drilling equipment.

A four-inch diameter PVC pipe was installed (grouted) for borehole geophysical surveys. Geophysics included natural gamma (clay content and lithology), neutron (water content), and gamma-gamma (density), along with deviation and directional surveys. Color plots of the borehole geophysical data are included with the respective drill log and are located in Appendix A. After the logging was completed, the hole was abandoned by backfilling with cement grout.

Drill Hole DH-03-5

Exploration drill hole DH-03-5 was located approximately 900 feet south of Washington State Highway 24, west of Horsethief Point and within the dry Black Rock Creek channel at the base of Horsethief Mountain. Drill hole DH-03-5 was sited at the lowest point of the valley along the alternate alignment (refer to Drawing 33-100-3381). The hole was advanced to a total depth of 106.5 feet. The upper 32.5 feet were composed of alluvium (Qh). Samples were not obtained, but, based on drilling and cuttings returned, the material was designated as medium- to coarse-grained sand with fines, gravel, cobbles, and occasional boulders. Underlying the alluvium is the Ringold Formation (Tr). Based on drill cuttings returned, the formation from 32.5 to 106.5 feet (bottom of hole) was composed of sand and fines, with some gravel and scattered cobble and boulder-sized material. A possible slide block was encountered from 90.0 to 101.2 feet. The rock was shallow and may be a buried slide block that originated from the steep north limb of the Horsethief Mountain anticline, similar to Horsethief Point and the rock encountered in DH-03-2. The rock appeared to be Pomona Basalt. Core samples taken consisted of black to gray, fine-grained to slightly porphyritic (<5% phenocrysts), hard (H3), dense basalt. The core was moderately to slightly weathered (W4) with extensive oxidation of fracture surfaces extending into the body of the rock. The core was intensely fractured (FD7). Samples recovered ranged from fragments to 0.4 feet in length, but most of the core was less than 0.33 feet in length. The fracture dip angles were mostly 45 to 60 degrees from horizontal with smooth and planar surfaces. The RQD for the core run from 96.6 to 101.2 feet was 0 percent. Below the slide block the material was composed of poorly graded gravel with clay and sand (GP-GC). The drill hole was terminated at 106.5 feet due to the limits of the drilling equipment.

A four-inch diameter PVC pipe was installed for borehole geophysical surveys. Geophysics included natural gamma (clay content and lithology), neutron (water content), and gamma-gamma (density), along with deviation and directional surveys. Color plots of the borehole geophysical data are included with the respective drill log and are located in Appendix A. After the logging was completed, the hole was abandoned by backfilling with cement grout.

Deep Foundation Drill Hole

The subsurface in the Black Rock Valley consists of surficial deposits of loess and alluvium, underlain by the Ringold, Saddle Mountain Basalt, and Wanapum Basalt Formations (refer Drawing Nos. 33-100-3383 and -3384). The Grande Ronde Basalt Formation also underlies the site at depth, but was not drilled or sampled during these investigations. Drilling at the original damsite was terminated at or shortly into the Pomona Basalt (refer to Drawing 33-100-3382). The maximum depth of drilling at the original site was 250 feet. Drilling for the deep hole (DH-04-1) at the alternate alignment was intended to be about 400 feet or approximately two-thirds the height of the potential dam, but was ultimately extended to over 560 feet in order to fully penetrate the Mabton Interbed. The deep hole also served as an observation well for down-hole water testing in a companion hole (DH-04-2). Results of the water testing in DH-04-2 and a discussion of aquifer characteristics are presented in *Appraisal Assessment of Hydrogeology at Black Rock Damsite, Technical Series No. TS-YSS-6* (Bureau of Reclamation, 2004b).

Drill Hole DH-04-1

Exploration drill hole DH-04-1 was drilled about 230 feet north of Washington State Highway 24, near the middle of the valley (refer to Drawing 33-100-3381). Continuous core samples were taken from the ground surface to the bottom of the hole at 562.3 feet.

The Black Rock Valley floor and slopes of the surrounding hills are mantled with wind-blown silt or loess (Qe). Loessial samples from DH-04-1 were composed of sandy silt s(ML). High-pressure air was used to advance the casing and core barrel in the loess. The resultant sample recovery was poor in the upper 5.0 feet and good from 5.0 to 7.0 feet. Samples contained about 70 percent nonplastic fines and about 30 percent fine sand, with some organic material in the upper few feet.

The alluvium (Qh) underlying the windblown silt was about 24.2 feet thick and was primarily coarse-grained gravel with medium- to coarse-grained sand and fines. Based on poor core recovery and drilling conditions, it was estimated that the alluvium also contained about 40 percent by volume cobble-sized (3- to 5-inch) material.

The Ringold Formation was distinguished from the overlying alluvium based on a change from predominantly coarse-grained to predominantly fine-grained material. The formation was about 58.8 feet thick and generally coarsened downward. From about 31.7 to 72.0 feet, the unit ranged from poorly graded sand with clay (SP-SC) to clayey sand with gravel (SC)g. From 72.0 to 80.0 feet, the material consisted of clayey sand with gravel and cobbles (SC)gc and the bottom from 80.0 to 90.5 feet was mostly cobbles with clayey sand (SC).

The uppermost unit of the Ellensburg Formation at the site is the Rattlesnake Ridge Interbed (Trr). The Rattlesnake Ridge Interbed was about 28.0 feet thick and the upper portion from 90.5 to 104.0 feet consisted of a weathered zone or palesol that may have developed prior to deposition of Ringold sediments. Below the weathered zone from 104.0 to 118.5 feet, the unit was composed of fine-grained, indurated silt- and sand-sized fragments of pumice and ash. This

lower zone was derived from reworking of the underlying invasive flow debris that formed the upper surface of the Pomona Basalt Member (Tp).

The shallowest bedrock unit at the site is the Pomona (Tp) Basalt Member of the Saddle Mountains Basalt formation. The Pomona Member was about 136.3 feet thick and the upper section, from 118.5 to 132.0 feet, was composed of sediments rafted to the upper flow surface. The rafted debris, commonly referred to as an "invasive flow," was composed of peperite. The peperite was essentially reworked and rafted material derived from the underlying Selah Interbed (Ts), consisting of a mixture of mottled (greenish yellow to reddish brown), moist, clayey gravel with sand (GC)s, and silty gravel with sand (GM)s. The invasive flow top appeared highly permeable as indicated by substantial fluid losses once the unit was encountered during drilling.

The peperite that formed the upper portion of the flow and the basaltic bedrock were separated by a 12-foot-thick layer of poorly graded gravel (GP) composed of mostly fine, hard, subrounded to subangular clasts comprised of dense basalt, palagonitic basalt, and glassy basalt (obsidian). This layer represents a zone of heat alteration at the interface between the molten basaltic flow and the rafted sediments.

The body of the Pomona Basalt was primarily black to gray, slightly porphyritic, slightly weathered (W3), hard (H3), intensely fractured (FD7) basalt. The RQD from 145.3 to 254.8 feet (bottom of unit) ranged from 0 to 78 percent. For details of RQD refer to the log for drill hole DH-04-1 located in Appendix A.

The Selah Interbed (Ts) is a sedimentary unit underlying the Pomona basalt. The total thickness of the Selah Interbed was 25 feet. The unit consisted of massive, reddish orange to greenish yellow, intensely weathered (W7), soft (H3) to moderately hard (H4), intensely fractured (FD7) to slightly fractured (FD3) tuffaceous claystone, siltstone, and sandstone. The RQD from 254.8 to 277.1 feet (bottom of unit) ranged from 44 to 100 percent.

Because the Esquatzel and Umatilla Basalt Members (Teq/Tum) are difficult to distinguish and have similar physical characteristics, the two units are grouped together for discussion. The total thickness of the unit was 191 feet. The basalt was primarily black to gray, fine-grained, hard basalt. Overall, the RQD from 277.1 to 467.0 feet was generally good and fractured zones were generally limited to the upper and lower boundary of the unit.

The Mabton Interbed (Ts) is a sedimentary unit underlying the Esquatzel and Umatilla Basalt. The total thickness of the Mabton was 88.8 feet. The unit consisted of massive, mottled light green to greenish tan, intensely weathered (W7), moderately soft (H5), slightly fractured (FD3), tuffaceous claystone, siltstone, and sandstone. The RQD from 467.0 to 555.8 feet (bottom of unit) ranged from 0 to 100 percent.

The drill hole was terminated in the Priest Rapids Basalt Member (Tpr) at 562.3 feet. The polymer-based drilling fluid was rapidly lost once the hole penetrated the Mabton sedimentary layer. The body of the Priest Rapids Member was primarily black to gray, slightly porphyritic,

slightly weathered (W3), hard (H3), intensely to moderately fractured (FD6) vesicular basalt. The RQD from 555.8 to 562.3 feet (bottom of unit) was 47 percent. Due to a total loss of drilling fluid, the hole was terminated at 562.3 feet. The fluid loss indicated that the upper portion of the formation was highly permeable.

A borehole geophysical survey was performed in the hole through the steel core drilling rods. Geophysics included natural gamma (clay content and lithology), neutron (water content), and gamma-gamma (density), along with deviation and directional surveys. After testing, the drill hole DH-04-1 was completed as a ground-water monitoring well (slotted-pipe piezometer) for ground-water testing in companion drill hole DH-04-2. Color plots of the borehole geophysical data are included with the respective drill log and are located in Appendix A.

Companion exploration drill hole DH-04-2 was drilled about 260 feet north of Washington State Highway 24, and about 30 feet north of drill DH-04-1 (refer to Drawing 33-100-3381). The hole was drilled for hydrologic testing. The results of the water testing and a discussion of aquifer characteristics are presented in *Appraisal Assessment of Hydrogeology at Black Rock Damsite, Technical Series No. TS-YSS-6* (Bureau of Reclamation, 2004b). Prior to water testing, a borehole geophysical survey was performed in the hole. Geophysics included natural gamma (clay content and lithology), neutron (water content), and gamma-gamma (density), along with deviation and directional surveys. Upon completion of hydrologic testing the hole was completed as a ground-water monitoring well (slotted-pipe piezometer). Color plots of the borehole geophysical data and drill log are located in Appendix A.

Faults

The ridges of the Yakima Fold Belt are generally asymmetrical, with one limb gently inclined while the other is steeply folded, often with a thrust fault near the base of the fold. This configuration exists at the Black Rock Damsite, which is between the Yakima Ridge anticline on the north and Horsethief Mountain/Rattlesnake Hills anticline on the south (refer to Drawing Nos. 33-100-3381, -3382, and -3383). The depth and geometry of the Horsethief Mountain Thrust Fault are not known. Additional investigations are needed to define these traits as well as history of movement along the fault and potential for generating future earthquakes.

Washington Infrastructure Services, Inc.'s study of the original damsite suggested that a more suitable damsite may lie further west of the original study area (Washington Infrastructure Services, Inc., 2003). The location further west was believed to be less complicated, due primarily to the presence of a potential north-south fault, delineated by the "Macho Linear" thought to place the bedrock nearer the ground surface (refer to Drawing 33-100-3381). Reclamation performed investigations at the alternate site to confirm the depth to bedrock. Drilling results showed that the depth to bedrock and overburden thickness at the alternate site were slightly greater than at the original damsite, indicating that if a north-south fault exists between the sites, the offset is insignificant (refer to Drawing No. 33-100-3384).

Landslides

The extent and causes of potential landslides in the study area, and impacts due to construction activities and reservoir operations need to be established. The landslides in the Yakima Fold Belt generally form on sloping limbs of the anticlines, due to failure of the lower strength sedimentary interbeds. The primary areas where these conditions exist include Horsethief Mountain (south abutment) and potentially along the south rim of the reservoir area.

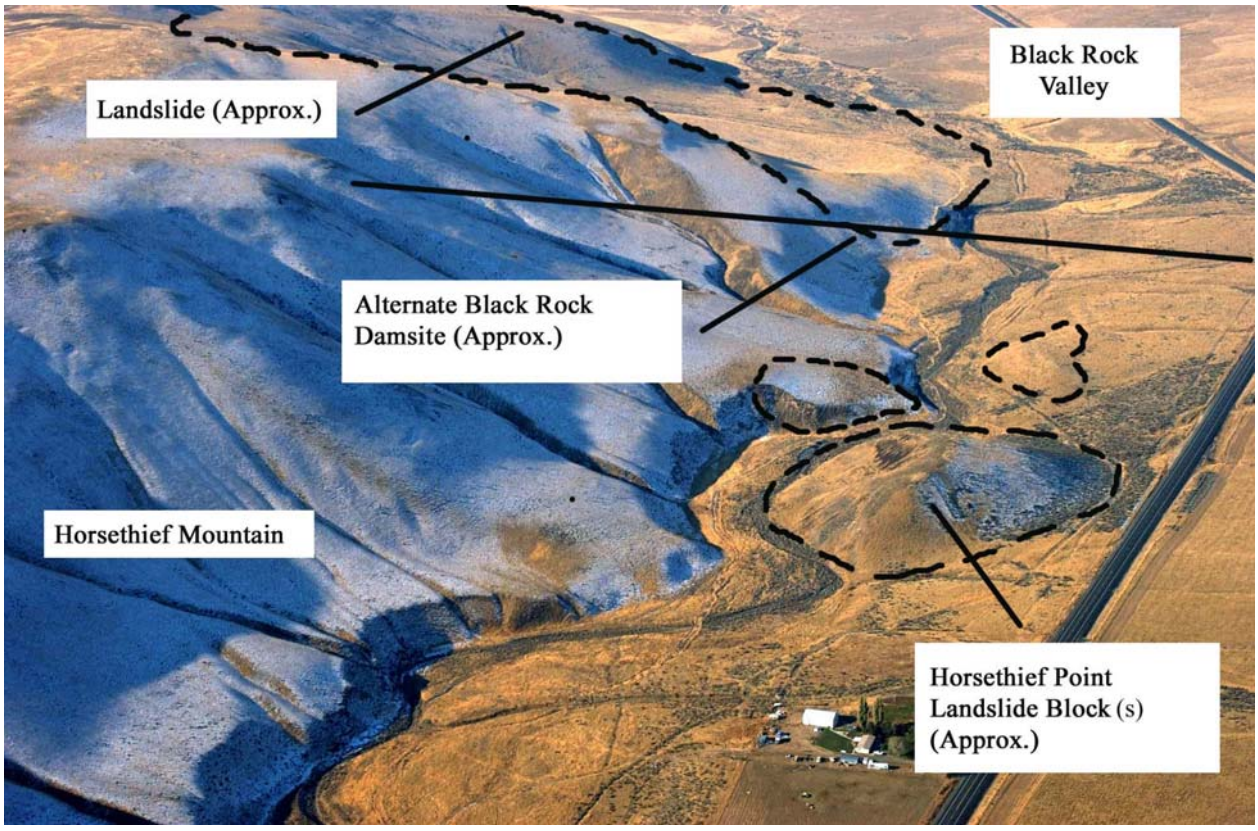
Several potential landslides have been identified on the Horsethief Mountain anticline (refer to Drawing 33-100-3381). One landslide is located on the north slope of the ridge upstream from the damsite (refer to Photograph 4). Horsethief Point is a prominent butte that projects from the valley floor upstream for the original damsite. This point appears to be a buried remnant of a landslide block that has moved off Horsethief Mountain (refer to Photograph 4). The third slide area is downstream from the damsite on the east slope of Horsethief Mountain (refer to Photograph 5).

Additional investigations are needed to evaluate the impacts of a potential reservoir on the landslide areas. In particular, potential landslides need to be identified and evaluated for impacts associated with the highway relocation along the south rim of the reservoir, the stability of slopes at the damsite during and after construction of the dam and appurtenant structures, and an evaluation of reservoir rim stability during reservoir operations.

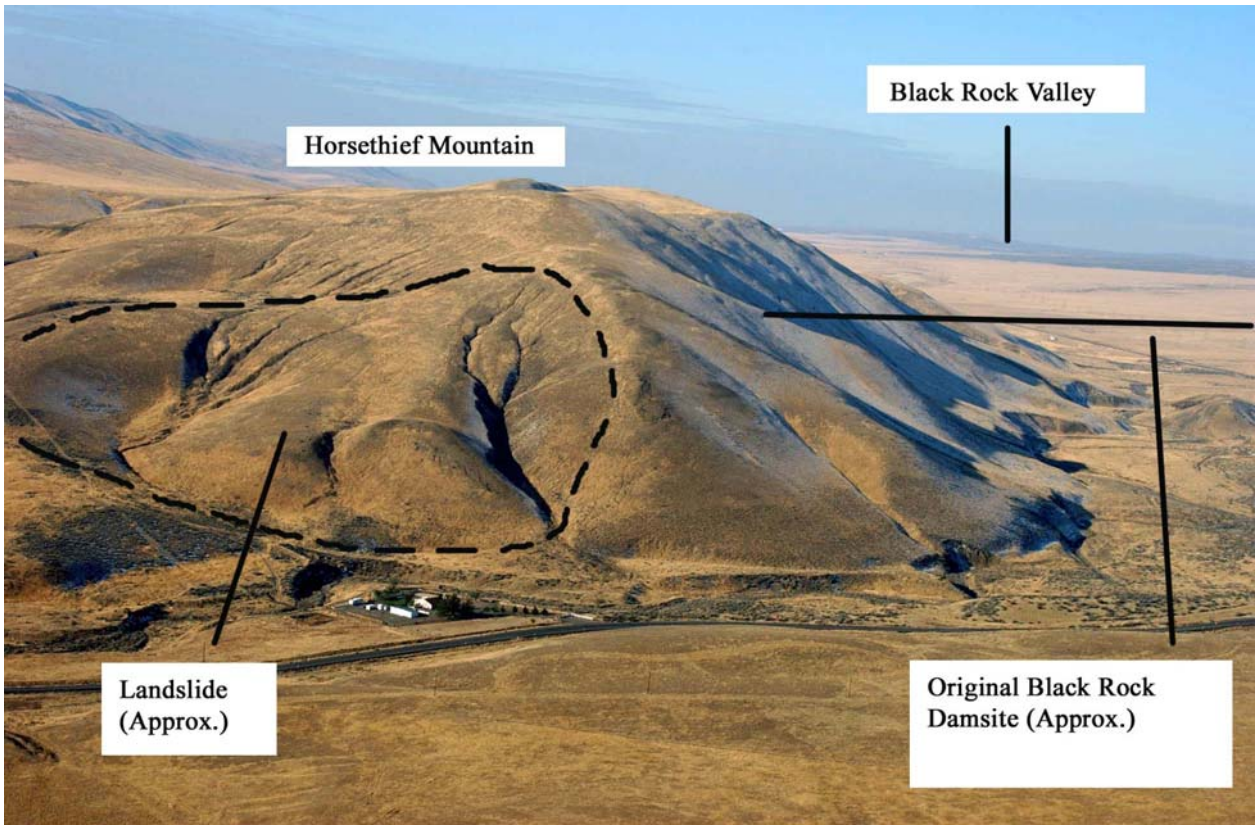
Comparison of Original and Alternate Damsites

As mentioned, Washington Infrastructure Services, Inc.'s report of the original damsite suggested that a more suitable damsite may lie further west of the original study area due to the presence of a potential north-south fault, referred to as the "Macho Linear" (refer to Drawing 33-100-3381) thought to place the bedrock nearer the ground surface (Washington Infrastructure Services, Inc., 2003).

Reclamation performed investigations at the alternate site between December 2003 and March 2004. These investigations involved drilling five shallow holes to define the bedrock surface and drilling one deep hole to confirm the stratigraphy of the deep foundation (refer to sections on *Bedrock Surface Drill Holes* and *Deep Foundation Drill Holes*). The exploratory drilling indicated that the depth to bedrock and overburden thickness at the alternate site was slightly greater than the original site. The depth to bedrock indicates that the potential offset along the postulated north-south fault, if the fault exists, is insignificant.



Photograph 4. View looking west at Horsethief Mountain, which forms the south (right) abutment at the Black Rock Damsite. Note landslide upstream of the alternate damsite on the northwest slope of the mountain. Horsethief Point and smaller rock outcrops to the west may be remnants of landslide debris derived from the north slope of the mountain. Black Rock Damsite, Yakima River Basin Water Storage Feasibility Study, Washington – Bureau of Reclamation photograph taken by D.M. Walsh, November 6, 2003.



Photograph 5. View looking west at Horsethief Mountain, which forms the south (right) abutment at the Black Rock Damsite. Note the landslide downstream and south of the original damsite on the east slope of the mountain. Black Rock Damsite, Yakima River Basin Water Storage Feasibility Study, Washington – Photograph taken by D.M. Walsh, November 6, 2003.

Engineering estimates based on drill hole information show that for total embankment quantities, including above- and below-ground fill materials, the alternate site would require about 10,000,000 more cubic yards (yd^3) than the original site (Bureau of Reclamation, 2004a). Based on this data, the original damsite is the preferred alignment and no further study of the alternate damsite is planned.

The geology of the Black Rock Damsite was developed from the investigations conducted in December 2002 at the original site by Washington Infrastructure Services, Inc. (Washington Infrastructure Services, Inc., 2003). Both of the damsites are underlain by the same geologic units and the engineering properties of the shallow and deep foundation materials are similar at both damsites. Initial investigations indicate the site is adequate for construction of the dam. However, additional investigations are needed to confirm the amount of foundation excavation, the extent of foundation treatment needed, including grouting, and to evaluate potential landslides on the right abutment.

Recommendations for Future Investigations

If the Black Rock alternative proceeds to a feasibility-level study, recommended items for future investigations at the original damsite are as follows:

Maximum Section Area

Additional drilling will be needed to define the geometry of the Ringold Formation and top of bedrock with emphasis on a suitable intermediate foundation within the Ringold, and to define the extent and suitability of Elephant Mountain Basalt as a foundation, or determine if it will it be necessary to excavate down to the Pomona Basalt. Also additional water testing for permeability will help define criteria for grout curtain. Drill holes should be two-thirds the height of the dam or about 400 feet deep.

Abutment Areas

Additional drilling and water testing are needed to evaluate the permeability of the upper abutments. Water losses were highest in the upper abutment holes where little soil cover exists over the fractured rock. For details of water testing in the upper abutments at the original damsite, refer to the report entitled, *Black Rock Reservoir Study, Initial Geotechnical Investigation* (Washington Infrastructure Services, Inc., 2003). The permeability information will also help evaluate seepage losses through the reservoir rim.

Horsethief Mountain Thrust Fault

The location and geometry of the thrust fault in the right abutment are not well known. Additional investigations are needed to define geometry, slip rates, movement history, and earthquake potential. The investigations likely will require both drilling and trenching.

GROUND WATER

The results of the water testing and a discussion of aquifer characteristics are presented in *Appraisal Assessment of Hydrogeology at Black Rock Damsite, Technical Series No. TS-YSS-6* (Bureau of Reclamation, 2004b).

BORROW MATERIALS

Nineteen potential construction material sources were identified on both developed and undeveloped sites within approximately 35 miles of the site. Descriptions of existing and potential borrow sites (mines) are summarized on Table 1 and approximate locations are shown on Figure 4. Following is a general summary of material types and approximate quantities required for the large reservoir central-core rockfilled dam. Quantities are based on informal engineering estimates. For details of the various material types, refer to Appraisal Assessment of *Black Rock Project Facilities and Cost Estimates, Final Report, Technical Series No. TS-YSS-2* (Bureau of Reclamation, 2004a).

Material Descriptions

Material Type	Description	Approximate Quantity (cubic yards)
Impervious Fill	Silt, clay, sand, and gravel	9,000,000
Rockfill	Gravel- to boulder-sized rock	81,750,000
Filter/drain materials	Processed sand and gravel	2,780,000
Concrete sand/gravel	Processed sand and gravel	185,000*
Cement	Cement	52,200* (tons)

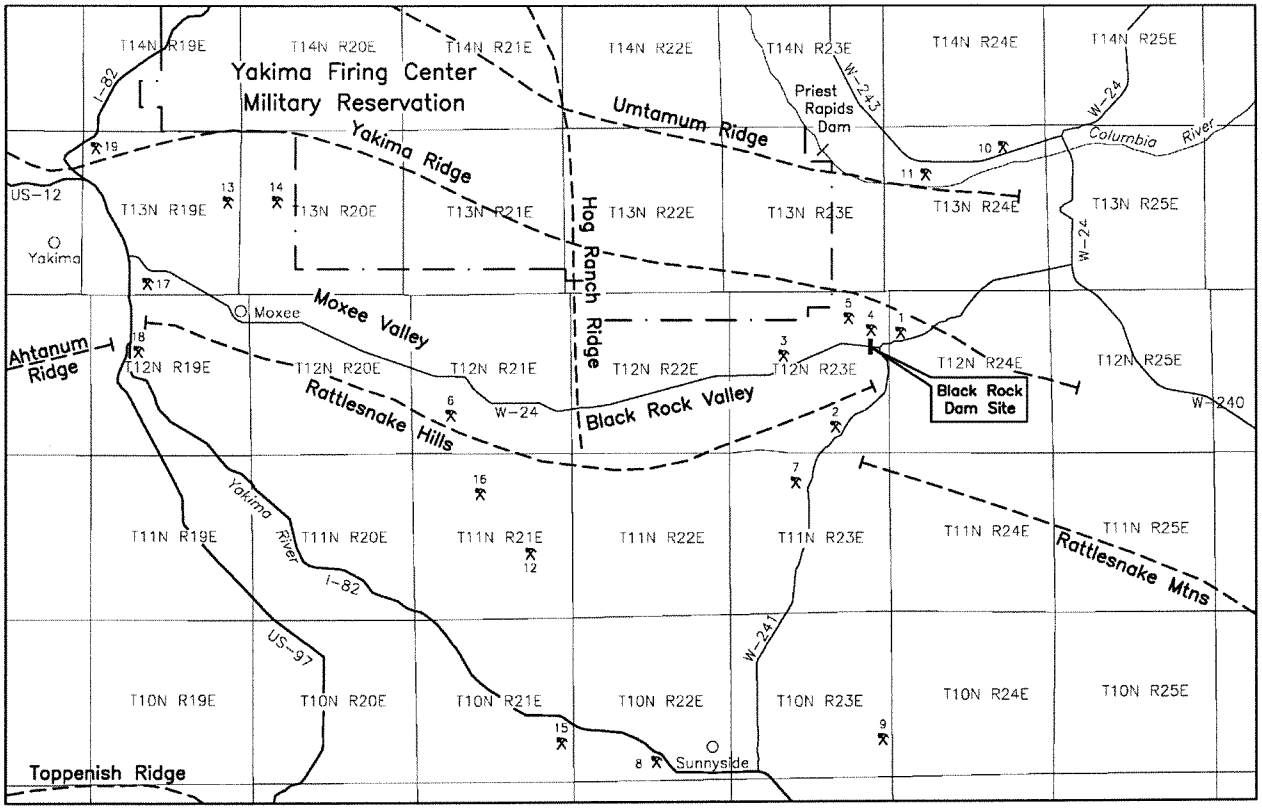
*Estimate for large reservoir concrete-faced rockfilled dam.

Black Rock Dam and associated structures can be constructed using materials mined locally from sources that consist of recent Yakima and Columbia River Alluvium, Post-Yakima Fold Belt Alluvium (including required excavation), and Columbia River Basalt (including required excavation). Impervious fill would have to be obtained by processing and separating fine-grained materials from Post-Yakima Fold Belt alluvial deposits located either in the Black Rock Valley or adjacent valleys. Borrow activities within the Black Rock Valley should be performed in a manner that would not alter the water-holding capability of the reservoir basin. Rockfill can be quarried from Columbia River Basalt and separated from required excavation. The nearest sources of material for processed sand and gravel are recent Columbia River alluvial deposits located east and northeast of the site. Yakima River deposits are located somewhat further away but can be utilized if necessary. Commercial sand and gravel mines are currently operating within both the Columbia and Yakima River floodplains.

TABLE 1

Summary of Existing and Potential Borrow Sites – Vicinity of the Black Rock Valley, Washington

Map No.	County	Owner/Permit Holder	Property Name	Section, Township, Range	Acreage	Depth (feet)	WDNR Permit Number	Commodity	App. Distance From Potential Dam Site (miles)
1	Benton	WDOT	OS-R-37	S. 7, T12N R24E	6.00	70	12813	Rockfill	2
2	Benton	Private	Dry Creek	S. 24, T12N, R23E	-	-	N/A	Impervious Fill	3
3	Yakima	WA State	Black Rock Valley (Black Rock Res.)	S. 16, T12N R23E	-	-	N/A	Impervious Fill & Rockfill	3
4	Yakima	Private	Black Rock Valley (Black Rock Res.)	S. 21, T12N R23E	-	-	N/A	Impervious Fill & Rockfill	3
5	Yakima	BLM	Yakima Ridge	S. 2, T12N R23E	-	-	N/A	Impervious Fill & Rockfill	3
6	Yakima	BLM/Private	Rattlesnake Hills	S. 34, T12N R23E	-	-	N/A	Impervious Fill & Rockfill	10
7	Yakima	Jeff Gamache Farms, Inc.	Black Starr	S.29, T12N R21E	15.00	25	12851	Rockfill	14
8	Yakima	Columbia Ready-Mix (Commercial)	Heffron	S. 34, T10N R22E	15.00	120	12907	Filter/Drain, Con. Aggregate & Sand	16
9	Yakima	WDOT	County Line	S. 25, T10N R23E	20.27	40	10631	Filter/Drain, Con. Aggregate & Sand	17
10	Grant	BOR	Columbia River	S. 3, T13N R24E	-	-	N/A	Filter/Drain, Con. Aggregate & Sand	18
11	Grant	Ellensburg Cement (Commercial)	Mattawa	S. 8, T13N R24E	36.00	40	12390	Filter/Drain, Con. Aggregate & Sand	20
12	Yakima	Yakima County	Liberty	S. 23, T11N R21E	16.27	50	10736	Filter/Drain, Con. Aggregate & Sand	23
13	Yakima	WDOT	Roza Hill	S. 13, T13N R19E	2.00	50	12202	Impervious Fill	24
14	Yakima	Cobra Const. Co. (Commercial)	Champoux Quarry	S. 17, T13N R20E	15.00	40	12000	Impervious Fill & Rockfill	24
15	Yakima	O.L. Luther Co., Inc. (Commercial)	O.L. Luther Pit	S.25, T10N R21E	80.00	40	12359	Filter/Drain, Con. Aggregate & Sand	24
16	Yakima	Superior (Commercial)	Zillah	S. 9, T11N R21E	100	-	13021	Filter/Drain, Con. Aggregate & Sand	25
17	Yakima	Central Pre-Mix Concrete (Commercial)	Riverside	S. 33, T13N R19E	40.00	40	11513	Filter/Drain, Con. Aggregate & Sand	25
18	Yakima	Columbia Ready Mix (Commercial)	Anderson Quarry	S. 17, T12N R19E	9.00	25	12801	Rockfill	26
19	Yakima	Superior (Commercial)	Rowley	S. 6, T13N R19E	62.01	200	12774	Impervious Fill & Rockfill	35



10
Mine site location and designation.

Approximate trace of ridge top.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA RIVER BASIN WATER STORAGE PROJECT - WASHINGTON

BLACK ROCK DAM SITE

EXISTING AND POTENTIAL BORROW SITE LOCATIONS

FIGURE 4

REFERENCES

Bureau of Reclamation, 2004a, Appraisal Assessment of Black Rock Project Facilities and Cost Estimates, Final Report, Technical Series No. TS-YSS-2: U.S. Department of the Interior, Bureau of Reclamation, Technical Service Center, Denver, Colorado, December.

Bureau of Reclamation, 2004b, Appraisal Assessment of Hydrogeology at Black Rock Damsite, Technical Series No. TS-YSS-6: U.S. Department of the Interior, Bureau of Reclamation, Pacific Northwest Region, Boise, Idaho, December.

Bureau of Reclamation, 2004c, Probabilistic Seismic Hazard Assessment for Appraisal Studies of the Proposed Black Rock Dam, Yakima River Basin Storage Feasibility Study, Washington, Technical Memorandum No. D-8330-2004-14: U.S. Department of the Interior, Bureau of Reclamation, Technical Service Center, Denver, Colorado, July.

Lenz, B.R., Walls, C.P., and Bentley, R.D., 2004, Geologic Investigation, Black Rock Dam, Alternate Damsite, Yakima County, Washington: Prepared for Bureau of Reclamation by Columbia Geotechnical Associates, Inc., February.

Reidel, S.P. and Campbell, N.P., 2003, Structure of the Yakima Fold Belt, Central Washington: In Swanson, T.W., ed., *Western Cordillera and Adjacent Areas, Geologic Society of America Field Guide 4*, Boulder, Colorado, p. 277-288.

Reidel, S.P., Martin, B.S., and Petcovic, H.L., 2003, The Columbia River Flood Basalts and the Yakima Fold Belt: In Swanson, T.W., ed., *Western Cordillera and Adjacent Areas, Geologic Society of America Field Guide 4*, Boulder, Colorado, p. 87-105.

Washington Infrastructure Services, Inc., 2003, Black Rock Reservoir Study, Initial Geotechnical Investigation: Prepared for Benton County Sustainable Development, January.

APPENDICES

APPENDIX A

Geologic and Geophysical Logs

Graphics Legends – Soil Classification and Hole Completion
Geologic Logs for Drill Hole Nos. DH-03-1 through DH-03-5
Core Photographs for DH-03-1 through DH-03-3 and DH-03-5
Geophysical Logs for Drill Hole Nos. DH-03-2 through DH-03-5
Geologic Logs for Drill Hole Nos. DH-04-1 and DH-04-2
Core Photographs for DH-04-1
Geophysical Logs for Drill Hole Nos. DH-04-1 and DH-04-2

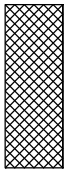
Results of Geochemical Analyses

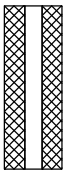
Summary of Samples for Geochemical Testing and Interpretation
Geotechnical Test Data

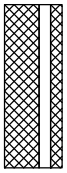
Geologic and Geophysical Logs

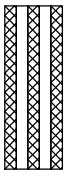
RECLAMATION
Managing Water in the West

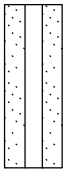

Auger Cuttings

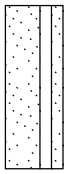

Bentonite Seal

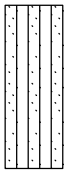

Bentonite Seal with 1 Pipe

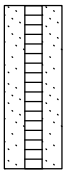

Bentonite Seal, 2 Pipe Group with 1 Pipe

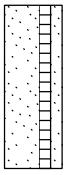

Bentonite seal, 2 Pipe Group with 2 Pipes

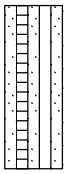

Sand Filter, 1 Pipe


Sand Filter, 2 Pipe Group, 1 Pipe

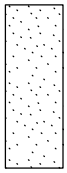

Sand Filter, 2 Pipe Group, 2 Pipes

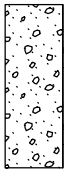

Slotted Pipe in Sand Filter, 1 Pipe

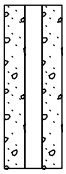

Slotted Pipe in Sand Filter, 2 Pipe Group, 1 Pipe

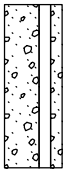

Slotted Pipe in Sand Filter, 2 Pipe Group, 2 Pipes

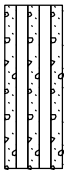

Slough to Bottom of Hole, Hole Caved, or Random Backfill


Sand Backfill to Bottom of Hole

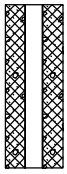

Cement

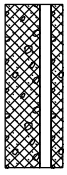

Cement, 1 Pipe

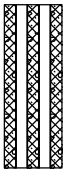

Cement, 2 Pipe Group, 1 Pipe


Cement, 2 Pipe Group, 2 Pipes


Bentonite Cement


Bentonite Cement, 1 Pipe

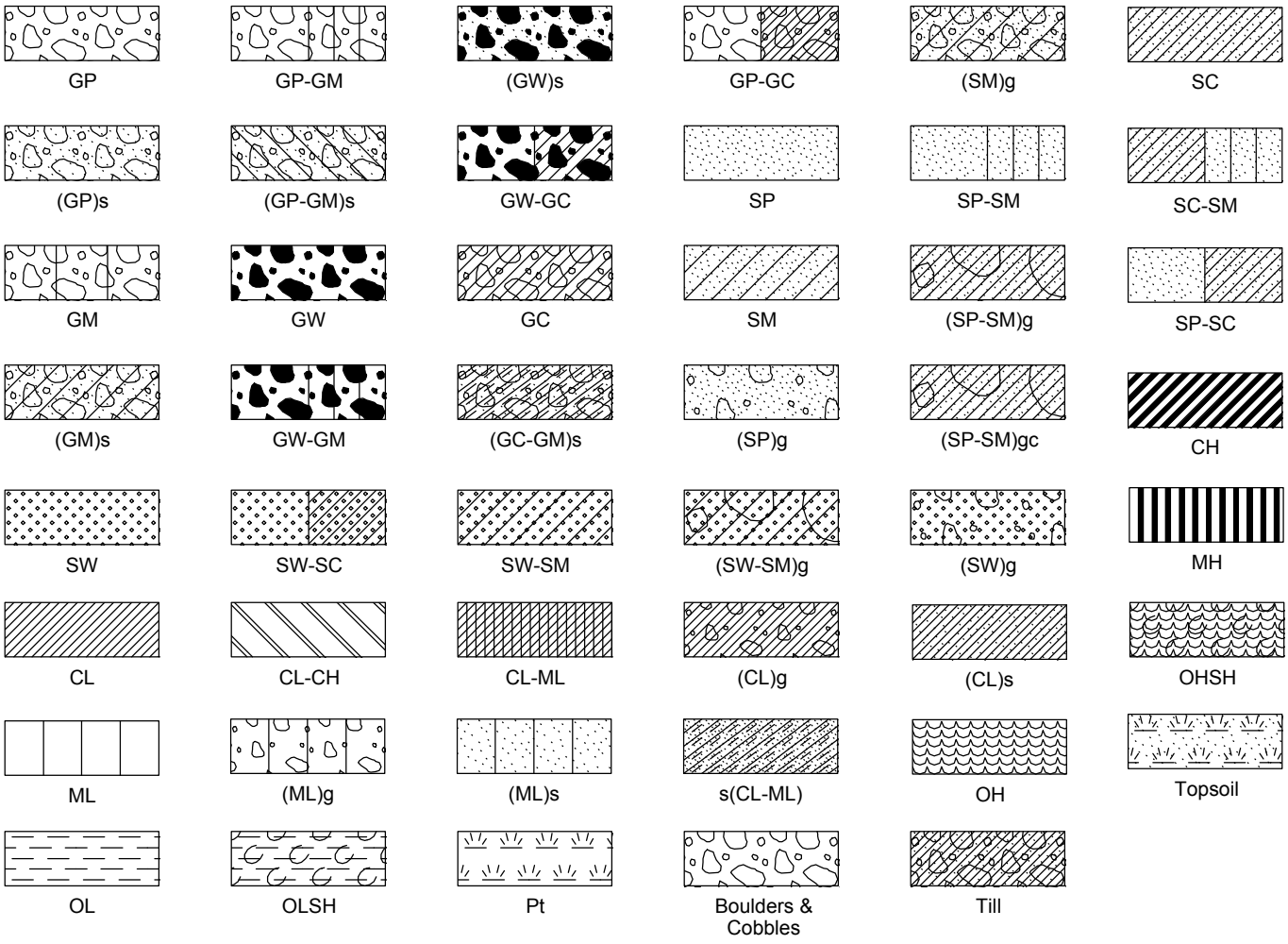

Bentonite Cement, 2 Pipe Group, 1 Pipe


Bentonite Cement, 2 Pipe Group, 2 Pipes

HOLE COMPLETION GRAPHICS LEGEND

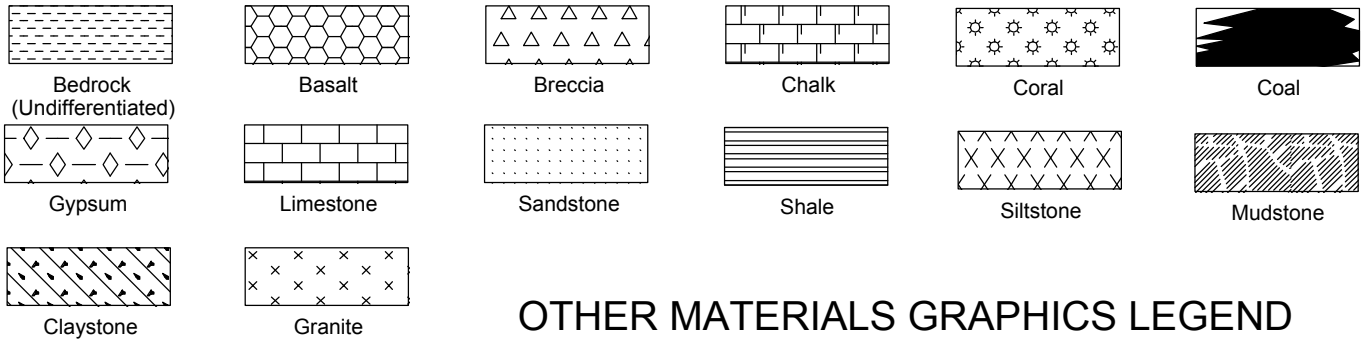
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

SOIL CLASSIFICATION GRAPHICS LEGEND

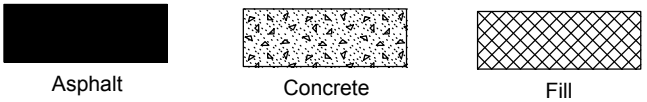


The Unified Soil Classification System (USCS) symbols above are defined and described in Designation USBR 5005-86, "Procedure for Determining Unified Soil Classification (Visual Method)", Designation USBR 5000-86, "Procedures for Determining Unified Soil Classification (Laboratory Method)", and Engineering Geology Field Manual, Volume 1, Second Edition, 1998, U. S. Department of the Interior, Bureau of Reclamation.

ROCK GRAPHICS LEGEND



OTHER MATERIALS GRAPHICS LEGEND



U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

GEOLOGIC LOG OF DRILL HOLE NO. DH-03-1

FEATURE: Black Rock Alternate Damsite
LOCATION: North of Washington State Highway 24
BEGUN: 12/4/03 FINISHED: 12/17/03
DEPTH AND ELEV OF WATER
LEVEL AND DATE MEASURED: Not Encountered

PROJECT: Yakima R. Basin Water Storage Feas. Study
COORDINATES: N 439,362.0 E 1,790,426.8
TOTAL DEPTH: 169.6
DEPTH TO BEDROCK: 146.9

STATE: Washington
GROUND ELEVATION: 1348.7
ANGLE FROM HORIZONTAL: AZIMUTH:
HOLE LOGGED BY: D.Stelma/R. McAffee
REVIEWED BY: R. A. Link

NOTES

All elevations measured from ground surface and are same as driller reported.

PURPOSE OF HOLE:
To determine the depth to the top of bedrock at the alternate damsite.

DRILL SETUP:
Setup on original ground along the alternate Black Rock dam axis approximately 230 feet north of Washington State Highway 24

DRILLING EQUIPMENT:
0.0-95.0': Ingersoll-Rand A-200 truck-mounted rotary drill. 95.0-169.6': Gus Peck truck-mounted rotary drill.

DRILLER:
0.0-95.0': Chris Peterson.
95.0-169.6': Lenny Washburn.

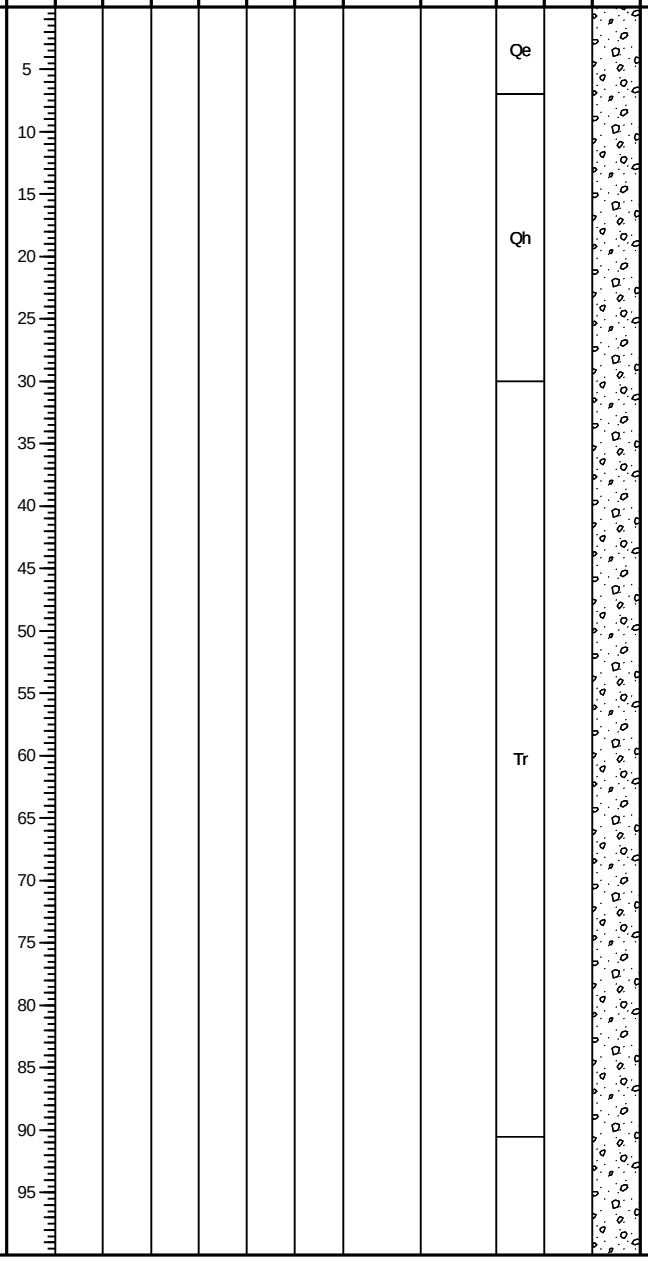
DRILLING METHODS:
0.0-165.0': Advanced 6-inch using the ODEX system (downhole hammer and compressed air).
165.0-169.6': Advanced hole with HQ wireline core barrel (2.50" I.D.) and diamond bit using clear water as circulating fluid.

DRILLING CONDITIONS:
0.0-9.0': Fast and smooth.
9.0-30.0': Slow and rough
30.0-38.0': Fast and smooth
38.0-69.0': Slow and rough
69.0-75.0': Fast and smooth
75.0-89.0': Slow and rough
89.0-118.0': Fast and smooth
118.0-169.6': Slow and rough

CASING RECORD:

Date	Sz	Depth Hole	Depth Cs
12/4	6"	29.0'	29.0'
12/5	6"	79.0'	49.0'
12/6	6"	97.0'	97.0'
12/12	6"	10.0'	10.0'
12/13	6"	125.0'	125.0'
12/15	6"	128.8	128.8'
12/16	6"	145.0'	145.0'
12/17	6"	169.6'	169.6'

FLUID COLOR:



CLASSIFICATION AND PHYSICAL CONDITION

0.0-7.0': **QUATERNARY LOESS DEPOSITS (Qe).** Surficial deposits of silt with lesser amounts of clay, composed primarily of wind-blown silt with small amounts of fine sand and volcanic ash. Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

7.0-30.0': **QUATERNARY ALLUVIUM DEPOSITS (Qh).** Undifferentiated medium to coarse-grained sand with fines, gravels, cobbles and boulders composed primarily of basaltic detritus from local sources. Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

30.0-90.5': **TERTIARY RINGOLD FORMATION (Tr).** Composed of fluviolacustrine sand, silt and clay, with layers of hard, gray to black, angular to subrounded cobbles and gravels in a matrix of fine to coarse sand and fines near the middle and base of the unit. Material is generally well indurated. Descriptions are based on drilling conditions and cuttings retrieved from ODEX air discharge line.

30.0-38.0': SAND. About 100% medium to fine, hard, subrounded sand; white to tan, dry. Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

38.0-43.0': BOULDER. Black, fine grained aphanitic, dense basalt. Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

43.0-49.0': GRAVEL WITH SILT AND SAND. Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

49.0-69.0': SAND AND GRAVEL WITH SILT AND COBBLES. Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

69.0-75.0': SILTY SAND. About 60% medium to fine, hard, subrounded sand; about 40% fines with low to medium plasticity and medium toughness; white to tan, dry. Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

75.0-90.5'. GRAVEL WITH SILT, SAND AND SCATTERED COBBLES: Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

90.5-118.5': **TERTIARY RATTLESNAKE RIDGE MEMBER (Trr)** of the Miocene Ellensburg Formation. Unconsolidated gravel, sand and cobbles with silt and clay. Black, gray to mottled, weathered basalt and tuffaceous sediments. Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

118.5-169.6': **POMONA MEMBER (Tp)** of the Saddle Mountains Basalt Formation, Miocene Columbia River Basalt Group (CRB). Black to gray, hard, mostly fine grained, dense basalt with plagioclase phenocrysts comprising less than 5% of the rock. Descriptions are based on drilling conditions, cuttings retrieved from ODEX

COMMENTS: Samples were logged in the field using Designation USBR 5005-86, "Procedures for Determining Unified Soil Classification (Visual Method)."

Center column descriptors are defined in the Reclamation Engineering Geology Field Manual, Volume 1, Second Edition, distributed February 1999.

Cs = Casing Sz = Size of Casing I.D. = Inside Diameter O.D. = Outside diameter

Geologic unit descriptions and stratigraphy based partially on consulting discussions with Dr. Bentley and geologic interpretations presented in the following reports:

"Black Rock Reservoir Study, Initial Geotechnical Investigation, Prepared for Benton County Sustainable Development by Washington Infrastructures Services, Inc., Dated January 2003.

"Geologic Investigation Black Rock Dam, Alternate Dam Site, Yakima County, Washington, Prepared for U.S. Bureau of Reclamation by Columbia Geotechnical Associates, Inc., Dated February 12, 2004.

GEOLOGIC LOG OF DRILL HOLE NO. DH-03-1

FEATURE: Black Rock Alternate Damsite
LOCATION: North of Washington State Highway 24
BEGUN: 12/4/03 FINISHED: 12/17/03
DEPTH AND ELEV OF WATER
LEVEL AND DATE MEASURED: Not Encountered

PROJECT: Yakima R. Basin Water Storage Feas. Study
COORDINATES: N 439,362.0 E 1,790,426.8
TOTAL DEPTH: 169.6
DEPTH TO BEDROCK: 146.9

STATE: Washington
GROUND ELEVATION: 1348.7
ANGLE FROM HORIZONTAL: AZIMUTH:
HOLE LOGGED BY: D.Stelma/R. McAffee
REVIEWED BY: R. A. Link

NOTES

0.0-165.0': None (Drilled using air).
165.0-169.6': Grey

FLUID RETURN:
0.0-165.0': None (Drilled using air).
165.0-169.6': Drilled using clear water, 75% return.

WATER LEVEL DURING DRILLING:
12/4 Dry
12/5 Dry
12/6 Dry
12/12 Dry
12/13 Dry
12/15 Dry
12/16 Dry
12/17 Dry

WATER LEVEL AFTER DRILLING:
Not measured.

DRILLING TIME:
Drilling 96 hrs.
Moving 40 hrs.
Down 30 hrs.

(Totals for both drill crews, travel time not included)

HOLE COMPLETION:
0.0-165.0': Steel casing (welded) broke during extraction, casing section remained in hole from approx. 20.0-169.6'. Installed and grouted 4" diameter PVC in the hole for downhole geophysical testing.
165.0-169.6': Backfill grout.

0.0-165.0': The 4" PVC was cut off below ground surface and backfilled (tremied) with cement grout after geophysical logging was complete.

Note: Downhole geophysicals testing was adversely affected by the steel casing , the data was not usable.

DEPTH	% RECOVERY	SPT	ENGINEERING PROPERTIES: WEATHERING	HARDNESS	FRACTURE DENSITY	RQD	FIELD CLASSIFICATION	LAB CLASSIFICATION	GEOLOGIC UNIT	GRAPHIC	HOLE COMPLETION
105									Trr		
110											
115											
120									Ts		
125											
130											
135											
140											
145											
150									Tp		
155											
160											
165	100		W3	H3	FD7	26					

BOTTOM OF HOLE

CLASSIFICATION AND PHYSICAL CONDITION

air discharge line and HQ-size core sample.

118.5-146.9': **INVASIVE FLOW TOP (PEPERITE) CONSISTING OF SELAH INTERBED (Ts)** of the Ellensburg Formation, Miocene Columbia River Basalt Group (CRB). Pumicite material rafted to the top of the Pomona Basalt, composed of moderately soft tuffaceous clay, silt, sand and gravel. Descriptions are based on drilling conditions and cuttings retrieved from ODEX air discharge line, and core samples from adjacent drill hole DH-04-1.

118.5-126.9'. SILT, SAND AND GRAVEL: Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

126.9-132.0': SILT, SAND AND GRAVEL WITH BOULDERS AND COBBLES. Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

132.0-146.9': SILT, SAND AND GRAVEL WITH BOULDERS AND COBBLES. Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

146.9-165.0': BASALT. Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

165.0-169.6': BASALT. Black to gray, fine grained, dense basalt. Slightly Weathered (W3). Oxidation (iron and manganese) limited to fracture surfaces. Hard (H3). Core breaks with heavy hammer blow. Intensely Fractured (FD7). Core recovered in lengths from fragments to 0.4', mostly in lengths less than 0.3', joints are mostly subhorizontal with smooth and planar surfaces. Prior to removal from core barrel (undisturbed) the joints were mostly tight to slightly open.

169.6': BOTTOM OF HOLE.


SINCE 1946
U.S. GOVERNMENT
P-6
BLACK ROCK FEAS Study
ALTERNATE DAM SITE
DH-03-1
165° - 169'
165°
169'

GEOLOGIC LOG OF DRILL HOLE NO. DH-03-2

FEATURE: Black Rock Alternate Damsite
LOCATION: South of Washington State Highway 24
BEGUN: 12/4/03 FINISHED: 12/6/03
DEPTH AND ELEV OF WATER
LEVEL AND DATE MEASURED: Not Encountered

PROJECT: Yakima R. Basin Water Storage Feas. Study
COORDINATES: N 438,362.8 E 1,790,138.9
TOTAL DEPTH: 73.9
DEPTH TO BEDROCK: Not Encountered

STATE: Washington
GROUND ELEVATION: 1291.9
ANGLE FROM HORIZONTAL: AZIMUTH:
HOLE LOGGED BY: D.Stelma/R. McAffee
REVIEWED BY: R. A. Link

NOTES

All elevations measured from ground surface and are same as driller reported.

PURPOSE OF HOLE:
To determine the depth to the top of bedrock at the alternate damsite.

DRILL SETUP:
Setup on original ground approximately 310 feet upstream (west) of the alternate Black Rock dam axis about 30-feet north of Black Rock Creek.

DRILLING EQUIPMENT:
0.0-73.9': Gus Peck truck-mounted rotary drill.

DRILLER:
Lenny Washburn

DRILLING METHODS:
0.0-66.5': Advanced 6-inch using the ODEX system (downhole hammer and compressed air).
66.5-73.9': Advanced hole with HQ wireline core barrel (2.50" I.D.) and diamond bit using clear water as circulating fluid.

DRILLING CONDITIONS:
0.0-3.5': Fast and Smooth
3.5-73.9': Slow and rough drilling, core blocked (wedged and prevented advancement of the core barrel) at 68.7' and 69.8'.

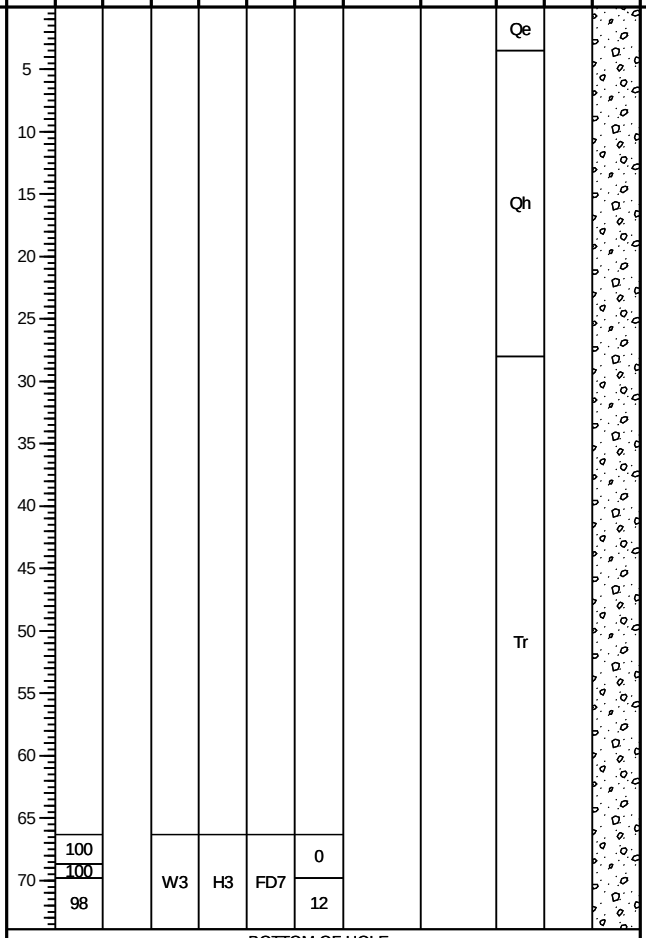
CASING RECORD:

Date	Sz	Depth Hole	Depth Cs
12/4	6"	47.0'	47.0'
12/5	6"	66.5'	66.5'
12/6	6"	73.9'	73.9'

FLUID COLOR:
0.0-66.3': None (Drilled using air).
66.3-73.9': No return.

FLUID RETURN:
0.0-66.3': None (Drilled using air).
66.3-73.9': Drilled using clear water, 0% return.

WATER LEVEL DURING DRILLING:
12/5: Dry
12/6: Dry



CLASSIFICATION AND PHYSICAL CONDITION

0.0-3.5': **QUATERNARY LOESS DEPOSITS (Qe).** Surficial deposits of silt with lesser amounts of clay, composed primarily of wind-blown silt with small amounts of fine sand and volcanic ash. Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

3.5-28.0': **QUATERNARY ALLUVIUM DEPOSITS (Qh).** Undifferentiated medium to coarse-grained sand with fines, gravels, cobbles and boulders composed primarily of basaltic detritus from local sources. Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

28.0-73.9': **TERTIARY RINGOLD FORMATION (Tr).** Composed of fluviolacustrine sand, silt and clay, with layers of hard, gray to black, angular to subrounded cobbles and gravels in a matrix of fine to coarse sand and fines near the middle and base of the unit. Material ranges from poorly to well indurated. Descriptions are based on drilling conditions, cuttings retrieved from ODEX air discharge line and HQ-size core samples.

28.0-33.0': SILTY TO CLAYEY GRAVEL WITH SAND AND COBBLES. Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

33.0-57.0': CLAYEY GRAVEL WITH SAND. Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

57.0-73.9': BASALT BLOCK. Black to gray, fine grained aphanitic, dense basalt. Descriptions are based on drilling conditions, cuttings retrieved from ODEX air discharge line and HQ -size core samples.

57.0-66.0': BASALT. Description based on drilling conditions and cuttings retrieved from ODEX air discharge line.

66.3-73.9': BASALT. Black to gray, fine grained, slightly porphyritic (<5% phenocrysts), dense basalt. Slightly Weathered (W3). Oxidation (iron and manganese) limited to fracture surfaces. Hard (H3). Core breaks with heavy hammer blow. Intensely Fractured ((FD7). Core recovered in lengths from fragments to 0.4', mostly in lengths less than 0.3', joint surfaces are smooth and planar, dips are mostly horizontal with lesser subvertical surfaces.

73.9': BOTTOM OF HOLE.

COMMENTS: Samples were logged in the field using Designation USBR 5005-86, "Procedures for Determining Unified Soil Classification (Visual Method)."

Center column descriptors are defined in the Reclamation Engineering Geology Field Manual, Volume 1, Second Edition, distributed February 1999.

Cs = Casing Sz = Size of Casing I.D. = Inside Diameter O.D. = Outside diameter

Geologic unit descriptions and stratigraphy based partially on consulting discussions with Dr. Bentley and geologic interpretations presented in the following reports:

"Black Rock Reservoir Study, Initial Geotechnical Investigation, Prepared for Benton County Sustainable Development by Washington Infrastructures Services, Inc., Dated January 2003.

"Geologic Investigation Black Rock Dam, Alternate Dam Site, Yakima County, Washington, Prepared for U.S. Bureau of Reclamation by Columbia Geotechnical Associates, Inc., Dated February 12, 2004.

GEOLOGIC LOG OF DRILL HOLE NO. DH-03-2

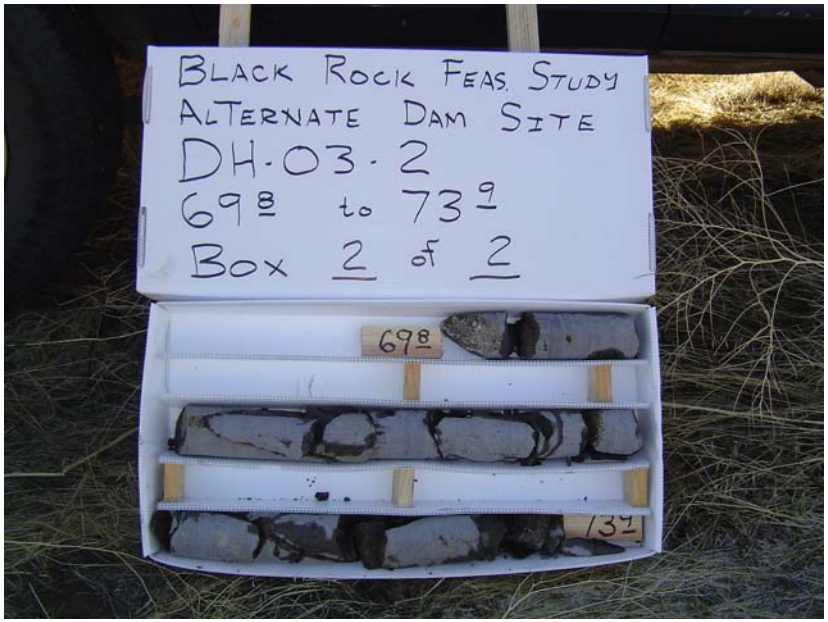
FEATURE: Black Rock Alternate Damsite
LOCATION: South of Washington State Highway 24
BEGUN: 12/4/03 FINISHED: 12/6/03
DEPTH AND ELEV OF WATER
LEVEL AND DATE MEASURED: Not Encountered

PROJECT: Yakima R. Basin Water Storage Feas. Study
COORDINATES: N 438,362.8 E 1,790,138.9
TOTAL DEPTH: 73.9
DEPTH TO BEDROCK: Not Encountered

STATE: Washington
GROUND ELEVATION: 1291.9
ANGLE FROM HORIZONTAL: AZIMUTH:
HOLE LOGGED BY: D.Stelma/R. McAffee
REVIEWED BY: R. A. Link

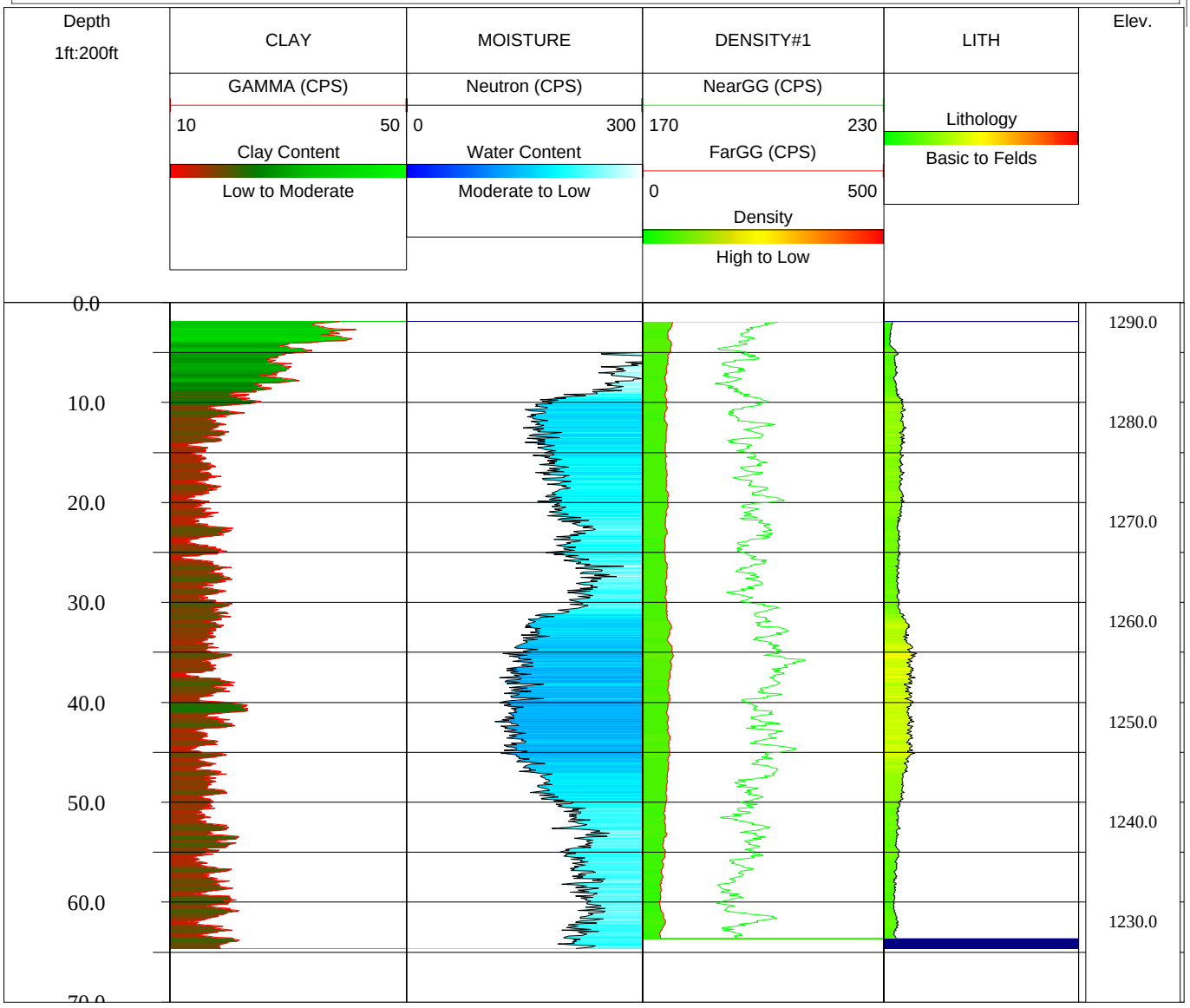
NOTES	DEPTH	% RECOVERY	SPT	ENGINEERING PROPERTIES: WEATHERING	HARDNESS	FRACTURE DENSITY	RQD	FIELD CLASSIFICATION	LAB CLASSIFICATION	GEOLOGIC UNIT	GRAPHIC	HOLE COMPLETION	CLASSIFICATION AND PHYSICAL CONDITION
WATER LEVEL AFTER DRILLING: Not measured. DRILLING TIME: Drilling 16 hrs Moving 4 hrs Down 10 hrs (Travel time not included) HOLE COMPLETION: 0.0-66.3': Installed and grouted 4" diameter PVC in the hole for down-hole geophysical testing. 66.3-73.9': Backfill grout. 0.0-66.3': The 4" PVC was cut off at ground surface and backfilled (tremied) with cement grout after geophysical logging was complete.													


BLACK ROCK FEAS. STUDY
ALTERNATE DAM SITE
DH-03-2
66 3/5 - 69 8/5
BOX 1 OF 2
66 3/5
68 7/5
69 8/5


BLACK ROCK FEAS. STUDY
ALTERNATE DAM SITE
DH-03-2
69 8/5 to 73 9/5
BOX 2 of 2
69 8/5
73 4/5

BUREAU OF RECLAMATION

PROJECT Black Rock HOLE NO. DH03-2



GEOLOGIC LOG OF DRILL HOLE NO. DH-03-3

FEATURE: Black Rock Alternate Damsite
LOCATION: North of Washington State Highway 24
BEGUN: 12/8/03 FINISHED: 12/9/03
DEPTH AND ELEV OF WATER
LEVEL AND DATE MEASURED: Not Encountered

PROJECT: Yakima R. Basin Water Storage Feas. Study
COORDINATES: N 441,929.6 E 1,790,321.8
TOTAL DEPTH: 99.0
DEPTH TO BEDROCK: 87.0

STATE: Washington
GROUND ELEVATION: 1516.0
ANGLE FROM HORIZONTAL: AZIMUTH:
HOLE LOGGED BY: D.Stelma/R. McAffee
REVIEWED BY: R. A. Link

NOTES

All elevations measured from ground surface and are same as driller reported.

PURPOSE OF HOLE:
To determine the depth to the top of bedrock at the alternate damsite.

DRILL SETUP:
Setup on original ground along the alternate Black Rock dam axis approximately 2700 feet north of Washington State Highway 24 (left abutment).

DRILLING EQUIPMENT:
Ingersoll-Rand A-200 truck-mounted rotary drill.

DRILLER:
Chris Peterson

DRILLING METHODS:
0.0-96.0': Advanced 6-inch using the ODEX system (downhole hammer and compressed air).
96.0-98.8': Advanced hole with HQ wireline core barrel (2.50" I.D.) and diamond bit using clear water as circulating fluid.
96.0-99.0': Reamed hole with 6-inch using the ODEX system (downhole hammer and compressed air).

DRILLING CONDITIONS:
0-17.0': Slow and rough
17.0-20.0': Fast and smooth
20.0-99.0': Slow and rough

CASING RECORD:
2003 Cs Depth Depth
Date Sz Hole Cs

12/8 6" 49.0' 49.0'
12/9 6" 99.0' 99.0'

FLUID COLOR:
0.0-96.0': None (Drilled using air).
96.0-98.5': No return.
98.5-99.0': None (Drilled using air).

FLUID RETURN:
0.0-96.0': None (Drilled using air).
96.0-98.5': 0% return.
98.5-99.0': None (Drilled using air).

WATER LEVEL DURING

DEPTH	% RECOVERY	SPT	ENGINEERING PROPERTIES: WEATHERING	HARDNESS	FRACTURE DENSITY	RQD	FIELD CLASSIFICATION	LAB CLASSIFICATION	GEOLOGIC UNIT	GRAPHIC	HOLE COMPLETION
0-95	100		W3	H3	FD8	0			Qe / Qh / Tr / Tp		

CLASSIFICATION AND PHYSICAL CONDITION

0.0-3.0': **QUATERNARY LOESS DEPOSITS (Qe).** Surficial deposits of silt with lesser amounts of clay, composed primarily of wind-blown silt with small amounts of fine sand and volcanic ash. Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

3.0-34.0': **QUATERNARY ALLUVIUM DEPOSITS (Qh).** Undifferentiated medium to coarse-grained sand with fines, gravels, cobbles and boulders composed primarily of basaltic detritus from local sources. Descriptions are based on drilling conditions and cuttings retrieved from ODEX air discharge line.

3.0-10.0'. SILTY GRAVEL WITH SAND AND COBBLES: Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

10.0-17.0'. GRAVEL: Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

17.0-20.0'. SILT: Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

20.0-34.0'. SAND, GRAVEL AND COBBLES: Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

34.0-87.0': **TERTIARY RINGOLD FORMATION (Tr).** Composed of fluviolacustrine sand, silt and clay, with layers of hard, gray to black, angular to subrounded cobbles and gravels in a matrix of fine to coarse sand and fines near the middle and base of the unit. Material ranges from poorly to well indurated. Descriptions are based on drilling conditions and cuttings retrieved from ODEX air discharge line.

34.0-80.0'. SAND, SILT AND GRAVEL: Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

80.0-87.0'. CLAY: Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

87.0-99.0': **POMONA MEMBER (Tp)** of the Saddle Mountains Basalt Formation, Miocene Columbia River Basalt Group (CRBG). Black to gray, hard, mostly fine grained dense basalt with plagioclase phenocrysts comprising less than 5% of the rock. Descriptions are based on drilling conditions, and cuttings retrieved from ODEX air discharge line, and HQ-size core sample.

87.0-96.0'. BASALT: Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

96.0-98.5': BASALT. Black to gray, fine grained, dense basalt. Slightly Weathered (W3). Oxidation (iron and manganese) limited to fracture surfaces. Hard (H3). Core breaks with heavy hammer blow. Very Intensely to Intensely Fractured (FD8). Core recovered in lengths from fragments to 0.2', mostly in lengths less than 0.1', joints are mostly horizontal with rough and irregular surfaces.

COMMENTS: Samples were logged in the field using Designation USBR 5005-86, "Procedures for Determining Unified Soil Classification (Visual Method)."

Center column descriptors are defined in the Reclamation Engineering Geology Field Manual, Volume 1, Second Edition, distributed February 1999.

Cs = Casing Sz = Size of Casing I.D. = Inside Diameter O.D. = Outside diameter

Geologic unit descriptions and stratigraphy based partially on consulting discussions with Dr. Bentley and geologic interpretations presented in the following reports:

"Black Rock Reservoir Study, Initial Geotechnical Investigation, Prepared for Benton County Sustainable Development by Washington Infrastructures Services, Inc., Dated January 2003.

"Geologic Investigation Black Rock Dam, Alternate Dam Site, Yakima County, Washington, Prepared for U.S. Bureau of Reclamation by Columbia Geotechnical Associates, Inc., Dated February 12, 2004.

GEOLOGIC LOG OF DRILL HOLE NO. DH-03-3

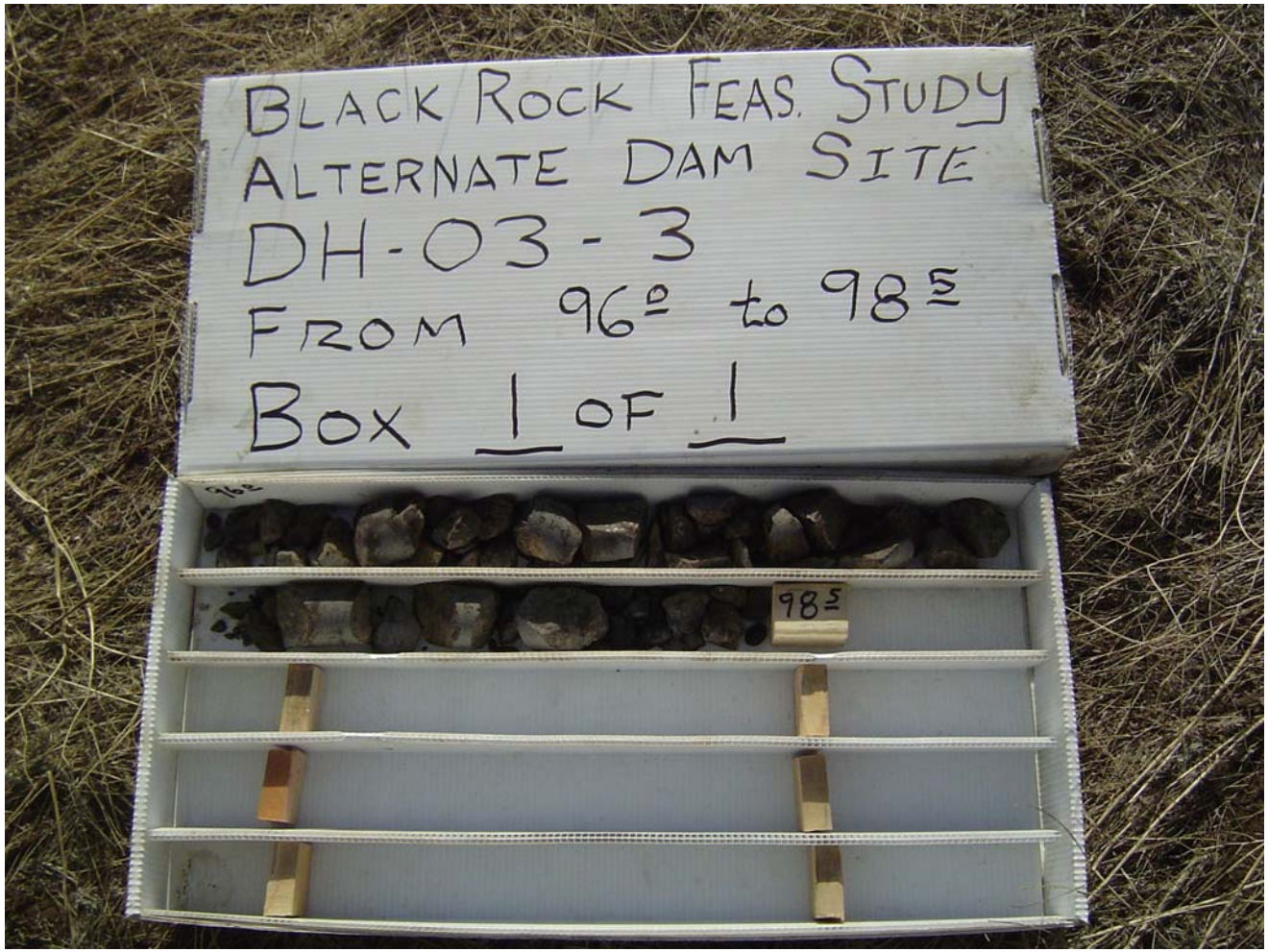
FEATURE: Black Rock Alternate Damsite
LOCATION: North of Washington State Highway 24
BEGUN: 12/8/03 FINISHED: 12/9/03
DEPTH AND ELEV OF WATER
LEVEL AND DATE MEASURED: Not Encountered

PROJECT: Yakima R. Basin Water Storage Feas. Study
COORDINATES: N 441,929.6 E 1,790,321.8
TOTAL DEPTH: 99.0
DEPTH TO BEDROCK: 87.0

STATE: Washington
GROUND ELEVATION: 1516.0
ANGLE FROM HORIZONTAL: AZIMUTH:
HOLE LOGGED BY: D.Stelma/R. McAffee
REVIEWED BY: R. A. Link

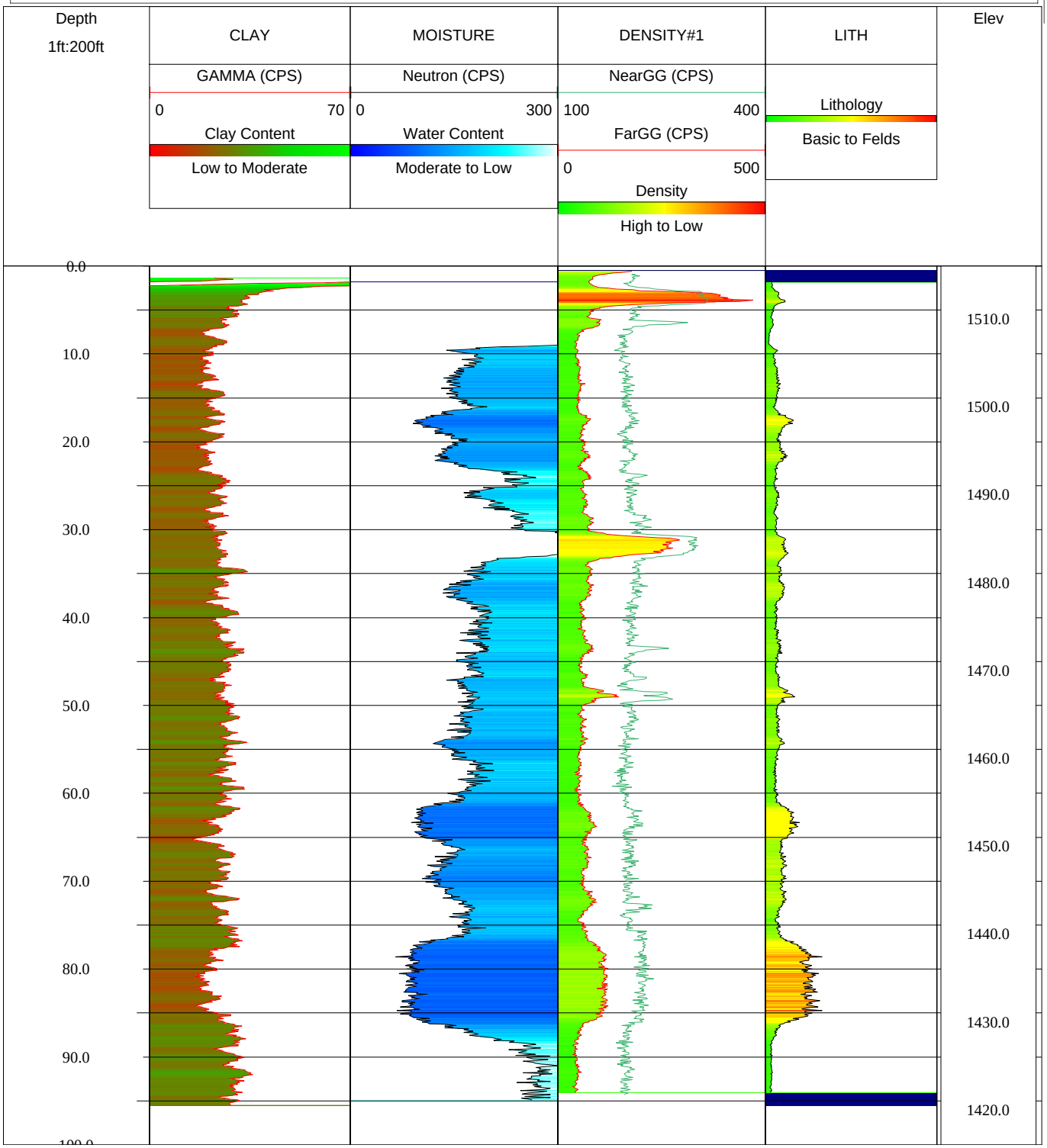
NOTES	DEPTH	% RECOVERY	SPT	ENGINEERING PROPERTIES: WEATHERING	HARDNESS	FRACTURE DENSITY	RQD	FIELD CLASSIFICATION	LAB CLASSIFICATION	GEOLOGIC UNIT	GRAPHIC	HOLE COMPLETION	CLASSIFICATION AND PHYSICAL CONDITION
DRILLING: 12/9: Dry WATER LEVEL AFTER DRILLING: Not measured. DRILLING TIME: Drilling 60 hrs. Moving 20 hrs. (Travel time not included) HOLE COMPLETION: 0.0-99.0': Installed and grouted 4" diameter PVC in the hole for downhole geophysical testing. 0.0-99.0': The 4" PVC was cut off at ground surface and backfilled (tremied) with cement grout after geophysical logging was complete.													98.5-99.0'. BASALT: Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line. 99.0': BOTTOM OF HOLE.

BOTTOM OF HOLE


BLACK ROCK FEAS. STUDY
ALTERNATE DAM SITE
DH-03-3
FROM 96' to 98'5
BOX 1 OF 1
98'5

BUREAU OF RECLAMATION

PROJECT Black Rock HOLE NO. DH03-3



GEOLOGIC LOG OF DRILL HOLE NO. DH-03-4

FEATURE: Black Rock Alternate Damsite
LOCATION: South of Washington State Highway 24
BEGUN: 12/17/03 FINISHED: 12/19/03
DEPTH AND ELEV OF WATER
LEVEL AND DATE MEASURED: Not Encountered

PROJECT: Yakima R. Basin Water Storage Feas. Study
COORDINATES: N 438,785.6 E 1,790,441.1
TOTAL DEPTH: 105.5
DEPTH TO BEDROCK: Not Encountered

STATE: Washington
GROUND ELEVATION: 1329.7
ANGLE FROM HORIZONTAL: AZIMUTH:
HOLE LOGGED BY: D.Stelma/R. McAffee
REVIEWED BY: R. A. Link

NOTES

All elevations measured from ground surface and are same as driller reported.

PURPOSE OF HOLE:
To determine the depth to the top of bedrock at the alternate damsite.

DRILL SETUP:
Setup on original ground along the alternate Black Rock dam axis approximately 350 feet south of Washington State Highway 24

DRILLING EQUIPMENT:
0.0-105.5': Ingersoll-Rand A-200 truck-mounted rotary drill.

DRILLER:
Chris Peterson

DRILLING METHODS:
Advanced 6-inch using the ODEX system (downhole hammer and compressed air).

DRILLING CONDITIONS:
0-58.0': Slow and rough
58.0-67.0': Fast and smooth
67.0-105.5': Slow and rough

CASING RECORD:

2003 Date	Cs Sz	Depth Hole	Depth Cs
12/17	6"	18.0'	18.0'
12/18	6"	78.0'	78.0'
12/19	6"	105.5'	105.5'

FLUID COLOR:
0.0-105.5': None (Drilled using air).

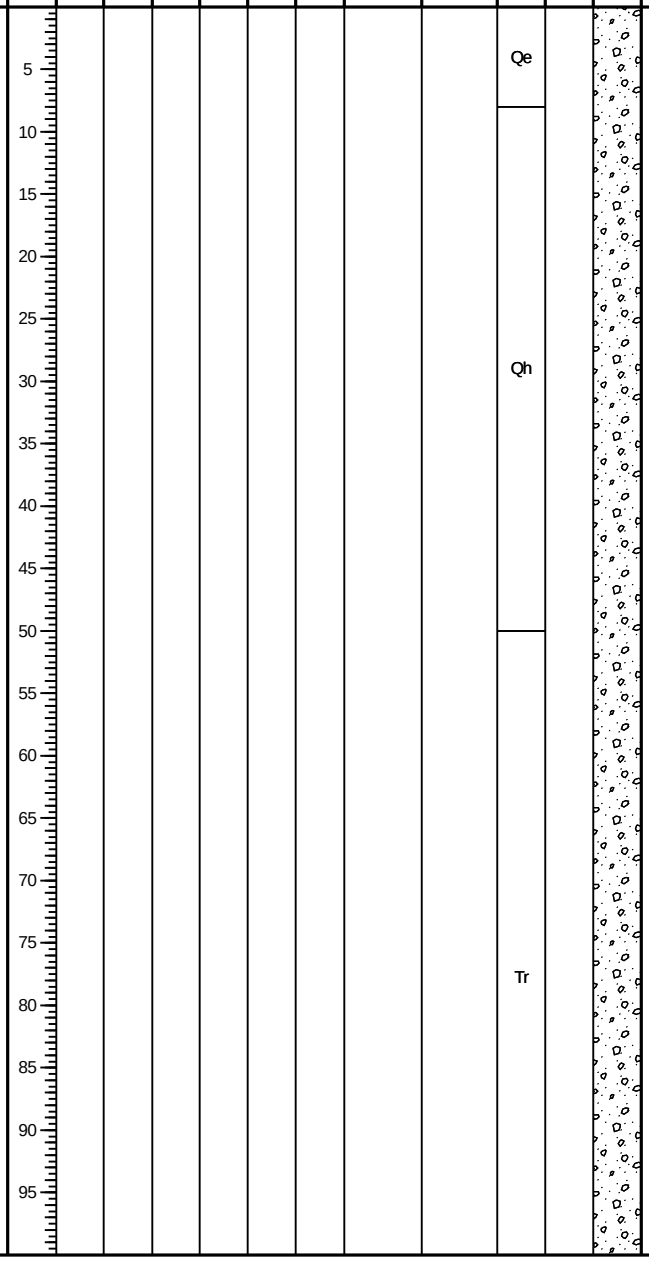
FLUID RETURN:
0.0-105.5': None (Drilled with air).

WATER LEVEL DURING DRILLING:
12/18: Dry
12/19: Dry

WATER LEVEL AFTER DRILLING:
Not measured.

DRILLING TIME:
Drilling 50 hrs.
Moving 10 hrs.

(Travel time not included)



CLASSIFICATION AND PHYSICAL CONDITION

0.0-8.0': **QUATERNARY LOESS DEPOSITS (Qe).** Surficial deposits of silt with lesser amounts of clay, composed primarily of wind-blown silt with small amounts of fine sand and volcanic ash. Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

8.0-50.0': **QUATERNARY ALLUVIUM DEPOSITS (Qh).** Undifferentiated medium to coarse-grained sand with fines, gravels, cobbles and boulders composed primarily of basaltic detritus from local sources. Descriptions are based on drilling conditions and cuttings retrieved from ODEX air discharge line.

8.0-18.0'. BOULDERS AND COBBLES WITH GRAVEL: Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

18.0-50.0'. BOULDERS AND COBBLES WITH GRAVEL, SILT AND SAND: Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

50.0-105.5': **TERTIARY RINGOLD FORMATION (Tr).** Composed of fluviolacustrine sand, silt and clay, with layers of hard, gray to black, angular to subrounded cobbles and gravels in a matrix of fine to coarse sand and fines near the middle and base of the unit. Material ranges from poorly to well indurated. Descriptions are based on drilling conditions and cuttings retrieved from ODEX air discharge line.

50.0-58.0': SILTY SAND WITH GRAVEL: Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

58.0-67.0': SILT WITH SAND: Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

67.0-73.0': BOULDERS AND COBBLES WITH SILTY GRAVEL: Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

73.0-78.0': SILTY SAND WITH GRAVEL. Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

78.0-88.0': SILT WITH SAND AND GRAVEL. Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

88.0-98.0': SILTY SAND AND GRAVEL. Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

98.0-105.5': BOULDERS AND COBBLES WITH GRAVEL, SILT AND SAND. Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.

105.5': BOTTOM OF HOLE.

COMMENTS: Samples were logged in the field using Designation USBR 5005-86, "Procedures for Determining Unified Soil Classification (Visual Method)."

Center column descriptors are defined in the Reclamation Engineering Geology Field Manual, Volume 1, Second Edition, distributed February 1999.

Cs = Casing Sz = Size of Casing I.D. = Inside Diameter O.D. = Outside diameter

Geologic unit descriptions and stratigraphy based partially on consulting discussions with Dr. Bentley and geologic interpretations presented in the following reports:

"Black Rock Reservoir Study, Initial Geotechnical Investigation, Prepared for Benton County Sustainable Development by Washington Infrastructures Services, Inc., Dated January 2003.

"Geologic Investigation Black Rock Dam, Alternate Dam Site, Yakima County, Washington, Prepared for U.S. Bureau of Reclamation by Columbia Geotechnical Associates, Inc., Dated February 12, 2004.

USBR_PN_7 BLACK ROCK.GPJ USBR_PN.GDT 2/10/05 8:27:30 AM

GEOLOGIC LOG OF DRILL HOLE NO. DH-03-4

FEATURE: Black Rock Alternate Damsite
LOCATION: South of Washington State Highway 24
BEGUN: 12/17/03 FINISHED: 12/19/03
DEPTH AND ELEV OF WATER
LEVEL AND DATE MEASURED: Not Encountered

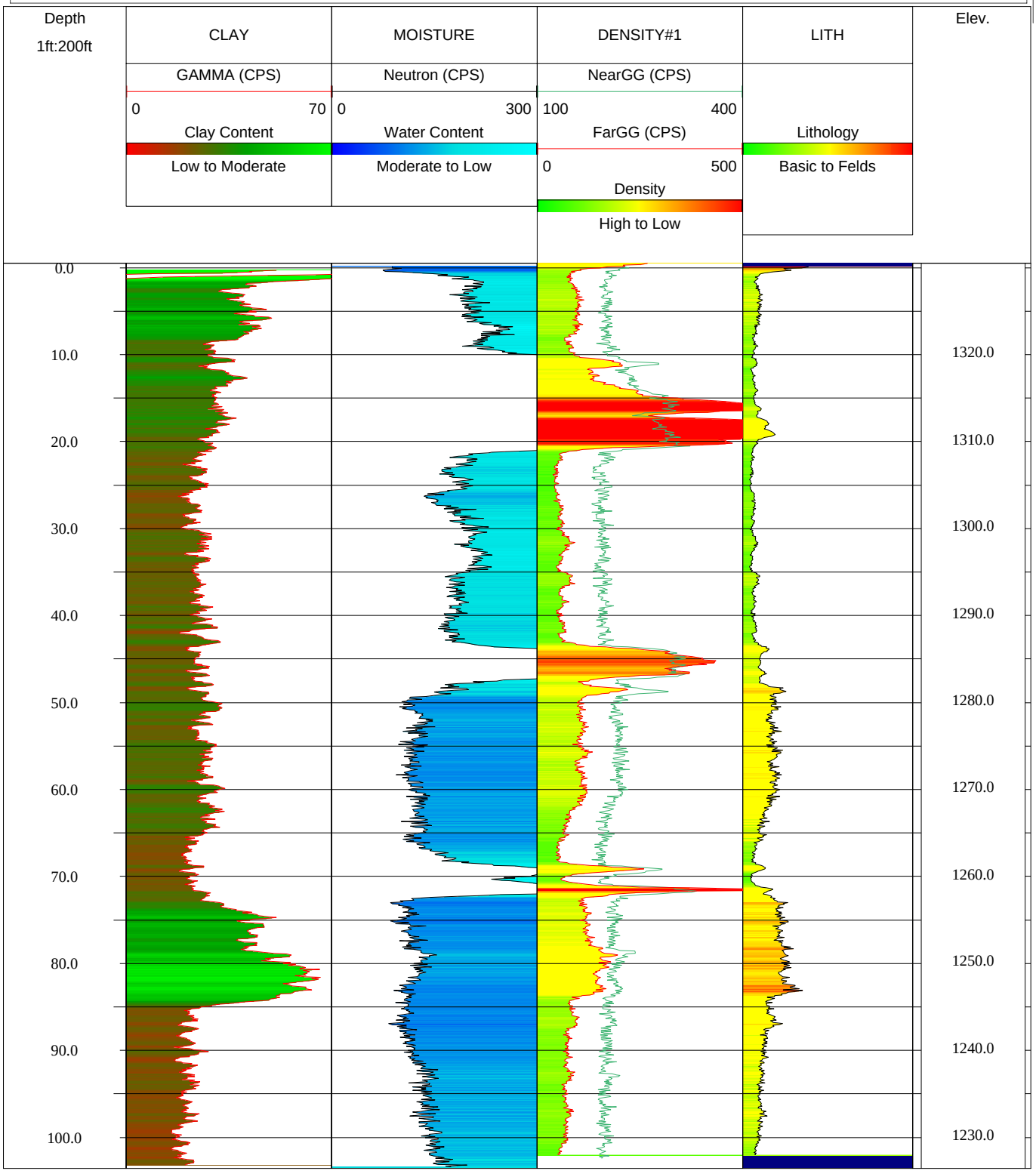
PROJECT: Yakima R. Basin Water Storage Feas. Study
COORDINATES: N 438,785.6 E 1,790,441.1
TOTAL DEPTH: 105.5
DEPTH TO BEDROCK: Not Encountered

STATE: Washington
GROUND ELEVATION: 1329.7
ANGLE FROM HORIZONTAL: AZIMUTH:
HOLE LOGGED BY: D.Stelma/R. McAffee
REVIEWED BY: R. A. Link

NOTES	DEPTH	% RECOVERY	SPT	ENGINEERING PROPERTIES: WEATHERING	HARDNESS	FRACTURE DENSITY	RQD	FIELD CLASSIFICATION	LAB CLASSIFICATION	GEOLOGIC UNIT	GRAPHIC	HOLE COMPLETION	CLASSIFICATION AND PHYSICAL CONDITION
HOLE COMPLETION: 0.0-105.5': Installed and grouted 4" diameter PVC in the hole for downhole geophysical testing. 0.0-105.5': The 4" PVC was cut off at ground surface and backfilled (tremied) with cement grout after geophysical logging was complete.	105												BOTTOM OF HOLE

BUREAU OF RECLAMATION

PROJECT Black Rock HOLE NO. DH03-04



110.0					1220.0

GEOLOGIC LOG OF DRILL HOLE NO. DH-03-5

FEATURE: Black Rock Alternate Damsite
LOCATION: South of Washington State Highway 24
BEGUN: 12/11/03 FINISHED: 12/16/03
DEPTH AND ELEV OF WATER
LEVEL AND DATE MEASURED: Not Encountered

PROJECT: Yakima R. Basin Water Storage Feas. Study
COORDINATES: N 438,210.9 E 1,790,467.2
TOTAL DEPTH: 106.5
DEPTH TO BEDROCK: Not Encountered

STATE: Washington
GROUND ELEVATION: 1285.5
ANGLE FROM HORIZONTAL: AZIMUTH:
HOLE LOGGED BY: D.Stelma/R. McAffee
REVIEWED BY: R. A. Link

NOTES	DEPTH	% RECOVERY	SPT	ENGINEERING PROPERTIES: WEATHERING	HARDNESS	FRACTURE DENSITY	RQD	FIELD CLASSIFICATION	LAB CLASSIFICATION	GEOLOGIC UNIT	GRAPHIC	HOLE COMPLETION	CLASSIFICATION AND PHYSICAL CONDITION
All elevations measured from ground surface and are same as driller reported. PURPOSE OF HOLE: To determine the depth to the top of bedrock at the alternate damsite. DRILL SETUP: Setup on original ground along the alternate Black Rock dam axis near the Black Rock Creek channel. DRILLING EQUIPMENT: Ingersoll-Rand A-200 truck-mounted rotary drill. DRILLER: Chris Peterson DRILLING METHODS: 0.0-8.0': Advanced 6-inch casing with casing hammer using 6-inch Odex and air to remove cuttings. 8.0-17.0': Advanced 6-inch casing with 5.5" downhole hammer and air to remove cuttings. 17.0-96.5': Advanced 6-inch casing with casing hammer using 6-inch Odex and air to remove cuttings. 96.5-102.8': Advanced hole with NQ wireline core barrel (3.75" I.D.) and diamond bit using clear water as circulating fluid. 102.8-106.5: Advanced 6-inch casing with casing hammer using 6-inch Odex and air to remove cuttings. DRILLING CONDITIONS: 0-58.0': Slow and rough 58.0-67.0': Fast and smooth 67.0-105': Slow and rough 105-106.5': Fast and smooth CASING RECORD: 2003 Cs Depth Depth Date Sz Hole Cs --- 12/11 6" 18.0' 18.0' 12/12 6" 48.0' 48.0' 12/13 6" 96.5' 96.5' 12/15 6" 106.5' 106.5' FLUID COLOR: 0.0-106.5': None (Drilled using air).	5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95	85		W4	H3	FD7	0			Qh Tr			0.0-32.5': **QUATERNARY ALLUVIUM DEPOSITS (Qh).** Undifferentiated medium to coarse-grained sand with fines, gravels, cobbles and boulders composed primarily of basaltic detritus from local sources. Descriptions are based on drilling conditions and cuttings retrieved from ODEX air discharge line. 0.0-8.0': SILTY SAND WITH GRAVEL. Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line. 8.0-18.0': BOULDERS AND COBBLES WITH GRAVEL. Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line. 18.0-32.5': BOULDERS AND COBBLES WITH GRAVEL, SILT AND SAND. Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line. 32.5-106.5': **TERTIARY RINGOLD FORMATION (Tr).** Composed of fluviolacustrine sand, silt and clay, with layers of hard, gray to black, angular to subrounded cobbles and gravels in a matrix of fine to coarse sand and fines near the middle and base of the unit. Material ranges from poorly to well indurated. Descriptions are based on drilling conditions and cuttings retrieved from ODEX air discharge line. 32.5-47.5': SAND AND CLAY. Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line. 47.5-68.0': SAND AND GRAVEL. Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line. 68.0-82.0': SILT AND SAND. Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line. 82.0-90.0': SAND AND GRAVEL. Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line. 90.0-101.2': BASALT BLOCK. Black to reddish gray, fine grained, dense basalt. Description is based on drilling conditions, cuttings retrieved from ODEX air discharge line and HQ -size core samples. 96.6-101.2': BASALT. Black to reddish gray, fine grained, slightly porphyritic (<5% phenocrysts), dense basalt. Moderately to Slightly Weathered (W4). Extensive oxidation (iron and manganese) on fracture surfaces and into body of rock. Hard (H3). Core breaks with heavy hammer blow. Intensely Fractured (FD7). Core recovered in lengths from fragments to 0.3', joint surfaces are smooth and planar and dipping about 45 to 60 degrees from horizontal. 101.2-102.8': POORLY GRADED GRAVEL WITH CLAY AND SAND (GP-GC). About 70% predominantly fine, hard, subangular gravel; about 20% fine to coarse, hard, subangular sand; about 10% fines with medium

COMMENTS: Samples were logged in the field using Designation USBR 5005-86, "Procedures for Determining Unified Soil Classification (Visual Method)."

Center column descriptors are defined in the Reclamation Engineering Geology Field Manual, Volume 1, Second Edition, distributed February 1999.

Cs = Casing Sz = Size of Casing I.D. = Inside Diameter O.D. = Outside diameter

Geologic unit descriptions and stratigraphy based partially on consulting discussions with Dr. Bentley and geologic interpretations presented in the following reports:

"Black Rock Reservoir Study, Initial Geotechnical Investigation, Prepared for Benton County Sustainable Development by Washington Infrastructures Services, Inc., Dated January 2003.

"Geologic Investigation Black Rock Dam, Alternate Dam Site, Yakima County, Washington, Prepared for U.S. Bureau of Reclamation by Columbia Geotechnical Associates, Inc., Dated February 12, 2004.

GEOLOGIC LOG OF DRILL HOLE NO. DH-03-5

FEATURE: Black Rock Alternate Damsite
LOCATION: South of Washington State Highway 24
BEGUN: 12/11/03 FINISHED: 12/16/03
DEPTH AND ELEV OF WATER
LEVEL AND DATE MEASURED: Not Encountered

PROJECT: Yakima R. Basin Water Storage Feas. Study
COORDINATES: N 438,210.9 E 1,790,467.2
TOTAL DEPTH: 106.5
DEPTH TO BEDROCK: Not Encountered

STATE: Washington
GROUND ELEVATION: 1285.5
ANGLE FROM HORIZONTAL: AZIMUTH:
HOLE LOGGED BY: D.Stelma/R. McAffee
REVIEWED BY: R. A. Link

NOTES

FLUID RETURN:
0.0-106.5': None (Drilled with air).

WATER LEVEL DURING DRILLING:
12/12: Dry
12/13: Dry
12/14: Dry
12/15: Dry

WATER LEVEL AFTER DRILLING:
Not measured.

DRILLING TIME:
Drilling: 40 hrs
Moving 10 hrs

(Travel time not included)

HOLE COMPLETION:
0.0-106.5': Installed and grouted 4" diameter PVC in the hole for downhole geophysical testing.

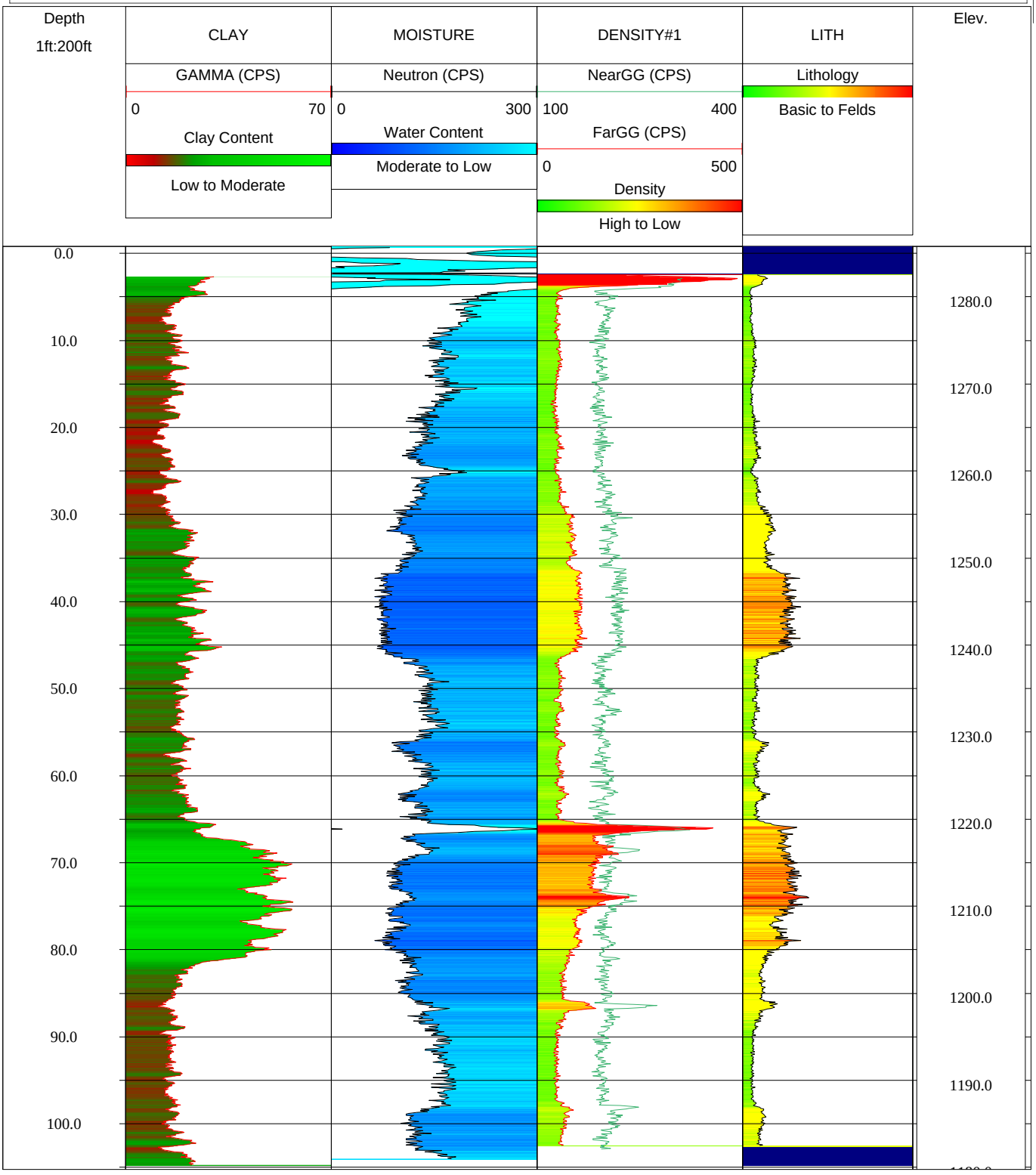
0.0-106.5': The 4" PVC was cut off at ground surface and backfilled (tremied) with cement grout after geophysical logging was complete.

DEPTH	% RECOVERY	SPT	ENGINEERING PROPERTIES: WEATHERING	HARDNESS	FRACTURE DENSITY	RQD	FIELD CLASSIFICATION	LAB CLASSIFICATION	GEOLOGIC UNIT	GRAPHIC	HOLE COMPLETION	CLASSIFICATION AND PHYSICAL CONDITION
	33											plasticity; dry, grayish brown to tan. Description is based on HQ -size core sample.
	31						GP-GC					102.8-106.5': SAND. Description is based on drilling conditions and cuttings retrieved from ODEX air discharge line.
105												106.5': BOTTOM OF HOLE.
												BOTTOM OF HOLE


BLACK ROCK FEAS. STUDY
ALTERNATE DAM SITE
DH-03-5
96⁶ - 102⁸
96⁶
100°
101²
102⁸

BUREAU OF RECLAMATION

PROJECT Black Rock HOLE NO. DH03-05



110.0					1180.0

GEOLOGIC LOG OF DRILL HOLE NO. DH-04-1

FEATURE: Black Rock Alternate Damsite
LOCATION: North of Washington State Highway 24
BEGUN: 1/30/04 FINISHED: 3/31/04
DEPTH AND ELEV OF WATER
LEVEL AND DATE MEASURED: 190.9 (1156.45) 3/31/04

PROJECT: Yakima R. Basin Water Storage Feas. Study
COORDINATES: N 439,357.5 E 1,790,476.4
TOTAL DEPTH: 562.3
DEPTH TO BEDROCK: 145.3

STATE: Washington
GROUND ELEVATION: 1347.4
ANGLE FROM HORIZONTAL: AZIMUTH:
HOLE LOGGED BY: Stelma/McAffee/Lyon
REVIEWED BY: R. A. Link

NOTES	DEPTH	% RECOVERY	SPT	ENGINEERING PROPERTIES: WEATHERING	HARDNESS	FRACTURE DENSITY	RQD	FIELD CLASSIFICATION	LAB CLASSIFICATION	GEOLOGIC UNIT	GRAPHIC	HOLE COMPLETION	CLASSIFICATION AND PHYSICAL CONDITION
All elevations measured from ground surface and are same as driller reported. PURPOSE OF HOLE: To determine foundation stratigraphy and rock fracturing characteristics for hydrogeologic testing. DRILL SETUP: Setup on original ground along the alternate Black Rock dam axis approximately 230 feet north of Washington State Highway 24. DRILLING EQUIPMENT: Truck mounted Ingersoll-Rand T-2 Truck mounted drill. DRILLER: Chris Peterson DRILLING METHODS: 0.0-183.0': Advanced hole with PQ wireline core barrel (3.336" I.D.) and diamond bit using polymer (EZ Mud) as circulating fluid. Advanced 6-inch surface casing to 148.0' to stabilize hole and enhance fluid return. Attempted to obtain drive samples (3" I.D.) at 13.2' and 22.0', both met refusal. 183.0-562.3': Advanced hole with HQ wireline core barrel (2.50" I.D.) and diamond bit using polymer (EZ Mud) as circulating fluid. DRILLING CONDITIONS: 0.0-13.2': Fast and smooth. 13.2-31.7': Slow to fast and rough. 31.7-75.0': Fast and smooth. 75.0-90.0': Slow and rough. 90.0-120.0': Fast and smooth. 120.0-145.5': Slow and rough, blocking. 145.5-180.0': Slow, smooth and hard with occasional blocking. 180.0-183.0': Slow and rough with frequent blocking. 183.0-211.4': Slow, smooth and hard. 211.4-255.8': Slow, smooth to rough with occasional blocking. 255.8-276.0': Slow and	5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95	8 80 40 0 19 48 8 100 100 67 88 94 0 94 100 100 100 100 100 100 100						SM (GP)c SP-SC SP (GC)sc (SC)g (SC)g Cobbles SC (SM)g		Qe Qh Tr			0.0-7.5': **QUATERNARY LOESS DEPOSITS (Qe).** Surficial deposits of silt with lesser amounts of clay, composed primarily of wind-blown silt with small amounts of fine sand and volcanic ash. Description is based on PQ-size core samples and cuttings returned. 7.5-31.7': **QUATERNARY ALLUVIUM DEPOSITS (Qh).** Undifferentiated medium to coarse-grained sand with fines, gravels, cobbles and boulders composed primarily of basaltic detritus from local sources. Description is based on PQ-size core samples and cuttings returned. 7.5-3`31.7': POORLY GRADED GRAVEL WITH COBBLES (GP)c. About 100% coarse, hard, subrounded gravel; dry, black (basalt) with white coatings (caliche). TOTAL SAMPLE (BY VOLUME): About 40% 3- to 5-inch, hard, subrounded cobbles; remainder minus 3 inch; maximum dimension, 125 mm. 31.7-90.5': **TERTIARY RINGOLD FORMATION (Tr).** Composed of fluviolacustrine sand, silt and clay, with layers of hard, gray to black, angular to subrounded cobbles and gravels in a matrix of fine to coarse sand and fines near the middle and base of the unit. Material is generally well indurated. Descriptions are based on PQ-size core samples. 31.7-38.0': POORLY GRADED SAND WITH CLAY (SP-SC). About 90% fine to medium, hard, subangular sand; about 10% fines with medium plasticity; maximum size, medium sand; dry, tan, homogeneous. 38.0-39.0': POORLY GRADED SAND WITH CLAY (SP-SC). About 90% fine to medium, hard, subrounded to subangular sand; about 10% fines with medium plasticity and medium toughness; maximum size, medium sand; dry to moist, gray to white, homogenous. 39.0-43.0': CLAYEY GRAVEL WITH SAND AND COBBLES (GC)sc. About 60% predominantly fine, hard, subrounded gravel; about 20% fine to coarse, soft to hard, subrounded sand; about 20% fines with medium plasticity and medium toughness; dry to moist, reddish brown, abundant iron oxide, soft weathered medium sand-sized plagioclase and mafic fragments, homogenous, no reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 40% 3- to 5-inch, hard, subrounded cobbles; remainder minus 3 inch; maximum dimension, 100 mm. 43.0-72.0': CLAYEY SAND WITH GRAVEL (SC)g. About 60% fine to coarse, hard, subrounded sand; about 20% fines with medium plasticity and medium toughness; about 20% fine, hard, subrounded gravel; maximum size, 20 mm; moist, reddish brown to brown, abundant iron oxide, scattered tuffaceous clasts (weathered basalt, cinder, pumice fragments), homogenous, no reaction with HCl. 72.0-80.0': CLAYEY SAND WITH GRAVEL AND COBBLES (SC)gc. About 50% fine to coarse, hard, subrounded sand; about 30% fine, hard, subrounded

COMMENTS: Samples were logged in the field using Designation USBR 5005-86, "Procedures for Determining Unified Soil Classification (Visual Method)."

Center column descriptors are defined in the Reclamation Engineering Geology Field Manual, Volume 1, Second Edition, distributed February 1999.

Cs = Casing Sz = Size of Casing I.D. = Inside Diameter O.D. = Outside diameter

Geologic unit descriptions and stratigraphy based partially on consulting discussions with Dr. Bentley and geologic interpretations presented in the following reports:

"Black Rock Reservoir Study, Initial Geotechnical Investigation, Prepared for Benton County Sustainable Development by Washington Infrastructures Services, Inc., Dated January 2003.

"Geologic Investigation Black Rock Dam, Alternate Dam Site, Yakima County, Washington, Prepared for U.S. Bureau of Reclamation by Columbia Geotechnical Associates, Inc., Dated February 12, 2004.

GEOLOGIC LOG OF DRILL HOLE NO. DH-04-1

FEATURE: Black Rock Alternate Damsite
LOCATION: North of Washington State Highway 24
BEGUN: 1/30/04 FINISHED: 3/31/04
DEPTH AND ELEV OF WATER
LEVEL AND DATE MEASURED: 190.9 (1156.45) 3/31/04

PROJECT: Yakima R. Basin Water Storage Feas. Study
COORDINATES: N 439,357.5 E 1,790,476.4
TOTAL DEPTH: 562.3
DEPTH TO BEDROCK: 145.3

STATE: Washington
GROUND ELEVATION: 1347.4
ANGLE FROM HORIZONTAL: AZIMUTH:
HOLE LOGGED BY: Stelma/McAffee/Lyon
REVIEWED BY: R. A. Link

NOTES	DEPTH	% RECOVERY	SPT	ENGINEERING PROPERTIES: WEATHERING	HARDNESS	FRACTURE DENSITY	RQD	FIELD CLASSIFICATION	LAB CLASSIFICATION	GEOLOGIC UNIT	GRAPHIC	HOLE COMPLETION	CLASSIFICATION AND PHYSICAL CONDITION
smooth. 276.0-303.2': Slow and smooth to rough with occasional blocking. 303.2-421.5': Slow, smooth and hard. 421.5-431.5': Slow and smooth to rough with occasional blocking. 431.5-451.5': Slow, smooth and hard. 451.5-471.2': Slow and smooth to rough with occasional blocking. 471.2-494.0': Slow, smooth and moderatley hard. 494.0-500.0': Fast, smooth and moderately rough. 500.0-555.8': Slow and smooth with occasional blocking. 555.8-562.3': Slow, smooth and hard. CASING RECORD: 2004 Cs Depth Depth Date Sz Hole Cs --- 01/30 6" 19.8' N/A 01/31 6" 19.8' 12.5' 02/02 6" 22.4' 22.0' 02/03 6" 31.7' 31.7' 02/04 6" 50.5' 31.7' 02/05 6" 50.5' 51.5' 02/06 6" 80.0' 51.5' 02/07 6" 105.0' 51.5' 02/09 6" 130.7' 51.5' 02/10 6" 132.0' 81.5' 02/11 6" 132.0' 132.0' 02/18 6" 142.5' 132.0' 02/19 6" 152.4' 142.0' 02/20 6" 155.0' 148.0' 02/21 6" 175.0' 148.0' 02/23 6" 183.0' 148.0' 02/24 4" 211.4' 183.0' 02/25 4" 238.2' 183.0' 02/26 4" 252.0' 183.0' 02/27 4" 271.4' 183.0' 02/28 4" 289.7' 183.0' 03/01 4" 310.3' 183.0' 03/02 4" 340.4' 183.0' 03/03 4" 358.2' 183.0' 03/09 4" 385.6' 183.0' 03/10 4" 411.5' 183.0' 03/11 4" 441.5' 183.0' 03/12 4" 469.6' 183.0' 03/13 4" 488.8' 183.0' 03/15 4" 509.6' 183.0' 03/16 4" 539.6' 183.0' 03/17 4" 562.3' 183.0' FLUID COLOR: 0.0-562.3': Drill mud (EZ mud with Diamond Seal). FLUID RETURN: 0.0-12.5': 100% 12.5-22.0': 75% 22.0-27.0': 80% 27.0-31.7': 90% 31.7-75.0': 100% 75.0-80.0': 95% 80.0-105.0': 100% 105.0-120.0': 95% 120.0-125.0': 100% 125.0-130.0': 70% 130.0-142.5': 0% 142.5-152.4': 97% 152.4-155.0': 80%	105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195 200 205 210 215	98 100 100 100 100 96 65 90 18 64 90 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100		W3	H3	FD7 FD8 FD7 FD9 FD6 FD5 FD7	6 0 10 0 21 65 27	Siltstone Peperite (GC)s GP Basalt		Trr Tp			gravel; about 20% fines with medium plasticity and medium toughness; moist, reddish brown, abundant iron oxide, homogenous, no reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 20% 3- to 5-inch, hard, surbrounded cobbles; remainder minus 3 inch; maximum dimension, 100 mm. 80.0-90.5': COBBLES WITH CLAYEY SAND. TOTAL SAMPLE (BY VOLUME): About 70% 3- to 5-inch, hard, surbrounded cobbles; about 20% 6- to 12-inch, hard, surbrounded cobbles; remainder minus 3 inch; maximum dimension, 150 mm. MINUS 3-inch FRACTION (BY VOLUME): About 80% fine to coarse, hard, subrounded sand; about 20% fines with medium plasticity and medium toughness; brown, abundant iron oxide, homogeneous, no reaction with HCl. 90.5-118.5': **TERTIARY RATTLESNAKE RIDGE MEMBER (Trr)** of the Miocene Ellensburg Formation. Unconsolidated gravel, sand and cobbles with silt and clay. Black, gray to mottled, weathered basalt and tuffaceous sediments (?). Descriptions are based on PQ-size core samples. 90.5-95.0': CLAYEY SAND (SC). About 60% fine to medium, hard, subrounded sand; about 40% fines with medium plasticity and medium toughness; maximum size, medium sand; moist, gray to tan, blocky structure, firm to dense, homogenous, no reaction with HCl. 95.0-104.0': SILTY SAND WITH GRAVEL (SM)g. About 70% fine to medium, hard, subrounded to subangular sand; about 20% fines with medium plasticity and medium toughness; about 10% fine, hard, subangular gravel; maximum size, medium sand; moist, gray, scattered white and yellow stringers of weathered plagioclase (pasty texture), traces of caliche, homogenous, firm to dense; weak reaction with HCl. 104.0-118.5': SILTSTONE (TUFFACEOUS). Reworked pumicite. Fine to medium grained, heterogenous, well indurated silt to medium-sand sized lithic fragments, pumice and ash. Intensely Weathered, material is altering to clay, core scratches with light to moderate knife pressure. 118.5-254.8': **POMONA MEMBER (Tp)** of the Saddle Mountains Basalt Formation, Miocene Columbia River Basalt Group (CRBG). Black to gray, hard, mostly fine grained, dense basalt with plagioclase phenocrysts comprising less than 5% of the rock. Descriptions are based on PQ and HQ-size core samples. 118.5-132.0': INVASIVE FLOW TOP (PEPERITE) CONSISTING OF SELAH INTERBED (Ts) of the Ellensburg Formation. Pumicite material rafted to the top of the Pomona Basalt, composed of reddish orange, black to gray, moderately soft tuffaceous clay, silt, sand and gravel. Descriptions are based on HQ-size core samples. 118.5-120.0': SILTY GRAVEL WITH SAND (GM)s (Pumicite). About 50% fine to coarse, hard, angular gravel; about 30% medium to coarse, hard, angular sand; about 20% fines with low plasticity; maximum size, 75 mm; moist, greenish yellow to reddish brown (mottled), abundant iron oxide, clasts composed of moderately weathered, dense to slightly vesicular basalt, chert nodules, cinder and pumice, heterogenous, no reaction with HCl. 120.0-132.0': CLAYEY GRAVEL WITH SAND AND COBBLES (GC)sc (Pumicite). About 50% fine to coarse, hard, angular gravel; about 30% medium to coarse, hard, angular sand; about 20% fines with medium plasticity; maximum size, 75 mm; moist, greenish yellow to reddish

GEOLOGIC LOG OF DRILL HOLE NO. DH-04-1

FEATURE: Black Rock Alternate Damsite
LOCATION: North of Washington State Highway 24
BEGUN: 1/30/04 FINISHED: 3/31/04
DEPTH AND ELEV OF WATER
LEVEL AND DATE MEASURED: 190.9 (1156.45) 3/31/04

PROJECT: Yakima R. Basin Water Storage Feas. Study
COORDINATES: N 439,357.5 E 1,790,476.4
TOTAL DEPTH: 562.3
DEPTH TO BEDROCK: 145.3

STATE: Washington
GROUND ELEVATION: 1347.4
ANGLE FROM HORIZONTAL: AZIMUTH:
HOLE LOGGED BY: Stelma/McAffee/Lyon
REVIEWED BY: R. A. Link

NOTES

155.0-165.0': 95%
165.0-221.4': 100%
221.4-230.1': 95%
230.1-271.4': 100%
271.4-275.1': 70%
275.1-283.1': 90%
283.1-297.7': 85%
297.7-298.4': 80%
298.4-300.3': 75%
300.3-310.3': 90%
310.3-320.4': 85%
320.4-340.4': 70%
340.4-349.4': 75%
349.4-358.2': 70%
358.2-361.5': 75%
361.5-381.5': 80%
381.5-391.5': 85%
391.5-421.5': 90%
421.5-426.6': 80%
426.6-469.6': 90%
469.6-561.6': 95%
561.6-562.3': 0%

WATER LEVEL DURING DRILLING:
(Drill fluid level from ground surface at start of shift)

Date	Fluid Level
01/31	Dry
02/02	8.2'
02/03	10.2'
02/04	0.0'
02/05	+3.9'
02/06	4.6'
02/07	4.7'
02/09	22.4'
02/10	95.4'
02/11	Dry
02/18	Dry
02/19	135.9'
02/20	1.9'
02/21	69.6'
02/23	0.0'
02/24	0.8'
02/25	+2.3'
02/26	1.1'
02/27	20.3'
02/28	136.7'
03/01	121.3'
03/02	122.9'
03/03	192.1'
03/09	192.2'
03/10	115.2'
03/11	94.5'
03/12	40.2'
03/13	7.8'
03/15	21.6'
03/16	20.4'
03/17	Dry

WATER LEVEL AFTER DRILLING:
3/30: 203.3' (el. 1144.1)
3/31: 190.9' (el. 1156.5)
4/02: 192.8' (el. 1154.6)

DRILLING TIME:
Drilling 390 hrs.
Moving: 20 hrs.

(Travel time not included)

HOLE COMPLETION:
0.0-18.0': Bentonite and cement surface seal.
18.0-118.0': Pea gravel.
118.0-183.0': Grout (cement) seal.

DEPTH	% RECOVERY	SPT	ENGINEERING PROPERTIES: WEATHERING	HARDNESS	FRACTURE DENSITY	RQD	FIELD CLASSIFICATION	LAB CLASSIFICATION	GEOLOGIC UNIT	GRAPHIC	HOLE COMPLETION	CLASSIFICATION AND PHYSICAL CONDITION
220	100				FD5	61						brown (mottled), abundant iron oxide, clasts composed of moderately weathered (palagonite on surfaces) dense to slightly vesicular basalt, chert nodules, cinder and pumice, heterogenous, no reaction with HCl.
					FD7	18						
225	100				FD5	78						TOTAL SAMPLE (BY VOLUME): About 30% 3- to 5-inch, hard, angular cobbles; remainder minus 3 inch; maximum dimension, 100 mm.
						20						
230	100				FD6	18						132.0-145.3': ALTERED UPPER FLOW CONTACT. POORLY GRADED GRAVEL (GP). About 100% predominantly fine, hard, subrounded to subangular gravel; dry to moist, gray, clasts composed of slightly weathered (palagonite on surfaces) glassy basalt. Description is based on HQ-size core samples.
235												
	57											
240	100											
	88											
245	27				FD9	9						145.3-150.8': BASALT. Black to gray, fine grained, slightly to moderately vesicular basalt. Most vesicles 1/4 to 1/2", largest 1-1/2" across, coated or filled with soft clay. Slightly Weathered (W3). Oxidation (iron and manganese) limited to fracture surfaces. Hard (H3). Core breaks with heavy hammer blow. Intensely Fractured (FD7). Core recovered in lengths from 0.1 to 0.4', mostly in lengths less than 0.3', joints are mostly horizontal with rough and irregular surfaces. Prior to removal from core barrel (undisturbed) the joints were mostly tight to slightly open.
250	100				FD6	66						
255	100			H5	FD3	100	Claystone					
				H6	FD6	44						Magnetic Polarity on Sample at 150.0': Reverse.
	100											
260	100		W7				Siltstone		Ts			150.8-160.0': BASALT. Black to gray, fine grained, dense basalt. Slightly Weathered (W3). Oxidation (iron and manganese) limited to fracture surfaces. Hard (H3). Core breaks with heavy hammer blow. Intensely Fractured (FD7). Core recovered in lengths from fragments to 0.6', mostly in lengths less than 0.3', joints dip 45 to 60 degrees, surfaces range from smooth and planar to rough and irregular. Prior to removal from core barrel (undisturbed) the joints were mostly tight to slightly open.
265				H4	FD3	70						
270	97											
	100						(GC)s					
275	97			H4	FD7	23						
280	85											160.0-170.0': BASALT. Black to gray, fine grained, dense basalt. Slightly Weathered (W3). Oxidation (iron and manganese) limited to fracture surfaces. Hard (H3). Core breaks with heavy hammer blow. Very Intensely to Intensely Fractured (FD8). Core recovered in lengths from fragments to 0.4', mostly in lengths less than 0.3', a single subvertical joint (with associated horizontal joints) runs the entire length of the interval, the subvertical joint surface ranges from smooth and planar to rough and irregular. Prior to removal from core barrel (undisturbed) the joints were mostly tight to slightly open.
285	98				FD6	33						
290	100											
295	93				FD9	5						170.0-180.0': BASALT. Black to gray, fine grained, dense basalt. Slightly Weathered (W3). Oxidation (iron and manganese) limited to fracture surfaces. Hard (H3). Core breaks with heavy hammer blow. Intensely Fractured (FD7). Core recovered in lengths from fragments to 0.6', mostly in lengths less than 0.3', the joint surfaces range from smooth and planar to rough and irregular. Prior to removal from core barrel (undisturbed) the joints were mostly tight to slightly open.
	100											
300	95											
305	100				FD2	96						
310												
315	99											180.0-183.0': BASALT. Black to gray, fine grained, dense basalt. Slightly Weathered (W3). Oxidation (iron and manganese) limited to fracture surfaces. Hard (H3). Core breaks with heavy hammer blow. Very Intensely Fractured (FD9). Core recovered mostly as fragments, a single subvertical joint (with associated horizontal joints) runs the entire length of the interval, the subvertical joint surface is rough and irregular and coated with iron and manganese oxide. Prior to removal from core barrel (undisturbed) the joints were mostly tight to slightly open.
320												
325	100				FD7	31						
330												
335	100				FD3	99						183.0-201.4': BASALT. Black to gray basalt, mostly fine grained with plagioclase phenocrysts up to 1-3 mm diameter. Phenocrysts comprise less than 5% of the rock. Slightly Weathered (W3). Oxidation (iron and

GEOLOGIC LOG OF DRILL HOLE NO. DH-04-1

FEATURE: Black Rock Alternate Damsite
LOCATION: North of Washington State Highway 24
BEGUN: 1/30/04 FINISHED: 3/31/04
DEPTH AND ELEV OF WATER
LEVEL AND DATE MEASURED: 190.9 (1156.45) 3/31/04

PROJECT: Yakima R. Basin Water Storage Feas. Study
COORDINATES: N 439,357.5 E 1,790,476.4
TOTAL DEPTH: 562.3
DEPTH TO BEDROCK: 145.3

STATE: Washington
GROUND ELEVATION: 1347.4
ANGLE FROM HORIZONTAL: AZIMUTH:
HOLE LOGGED BY: Stelma/McAffee/Lyon
REVIEWED BY: R. A. Link

NOTES	DEPTH	% RECOVERY	SPT	ENGINEERING PROPERTIES: WEATHERING	HARDNESS	FRACTURE DENSITY	RQD	FIELD CLASSIFICATION	LAB CLASSIFICATION	GEOLOGIC UNIT	GRAPHIC	HOLE COMPLETION	CLASSIFICATION AND PHYSICAL CONDITION
183.0-256.0': Bentonite seal. 256.0-266.0': Filter sand. 266.0-286.0': Slotted pipe (.020") with 1" diameter pvc riser and filter sand (#8-12). 286.0-288.0': Filter sand. 288.0-562.3': Bentonite seal. Note: Downhole geophysical testing was performed prior to extraction of core drilling rods.	340			W3	H3			Basalt		Teq/Tum			manganese) limited to fracture surfaces, phenocrysts are soft and discolored to a grayish white color. Hard (H3). Core breaks with heavy hammer blow. Intensely to Moderately Fractured (FD6). Core recovered in lengths from fragments to 0.6', mostly in lengths less than 0.4', the joint surfaces are mostly smooth and planar to irregular. Prominent subvertical joints were observed from 190.0-191.1', 191.7-194.0' and 192.3-195.3'. Prior to removal from core barrel (undisturbed) the joints were mostly tight to slightly open.
	345	100				FD7	20						
	350												
	355	99				FD4	78						
	360	97											
	365	100											201.4-210.7': BASALT. Black to gray basalt, mostly fine grained with plagioclase phenocrysts up to 1-2 mm diameter. Phenocrysts comprise less than 5% of the rock. Slightly Weathered (W3). Oxidation (iron and manganese) limited to fracture surfaces, phenocrysts are soft and discolored to a grayish white color. Hard (H3). Core breaks with heavy hammer blow. Moderately Fractured (FD5). Core recovered in lengths from fragments to 1.7', mostly in lengths less than 0.7', the joint surfaces are mostly smooth and planar to irregular. Numerous joints were weakly rehealed (silica), but separated upon handling, A single subvertical joint was observed from 208.0-209.3'. Prior to removal from core barrel (undisturbed) the joints were tight to slightly open.
	370						100						
	375	100											
	380												Magnetic Polarity on Sample at 201.4': Reverse.
	385	100					95						210.7-216.5': BASALT. Black to gray basalt, mostly fine grained with plagioclase phenocrysts up to 1-2 mm diameter. Phenocrysts comprise less than 5% of the rock. Slightly Weathered (W3). Oxidation (iron and manganese) limited to fracture surfaces, phenocrysts are soft and discolored to a grayish white color. Hard (H3). Core breaks with heavy hammer blow. Intensely Fractured (FD7). Core recovered in lengths from fragments to 0.4', mostly in lengths less than 0.3', the joint surfaces are mostly smooth and planar to irregular. Numerous joints were weakly rehealed (silica), but separated upon handling, A single subvertical joint was observed extending through the entire interval. Prior to removal from core barrel (undisturbed) the joints were tight to slightly open.
	390	100				FD3	98						
	395	100					92						
	400												
	405	100											216.5-222.2': BASALT. Black to gray basalt, mostly fine grained with plagioclase phenocrysts up to 1-2 mm diameter. Phenocrysts comprise less than 5% of the rock. Slightly Weathered (W3). Oxidation (iron and manganese) limited to fracture surfaces, phenocrysts are soft and discolored to a grayish white color. Hard (H3). Core breaks with heavy hammer blow. Moderately Fractured (FD5). Core recovered in lengths from 0.2 to 0.9', mostly in lengths of 0.7', the joint surfaces are mostly smooth and planar to irregular. Numerous joints were weakly rehealed (silica), but separated upon handling. Prior to removal from core barrel (undisturbed) the joints were tight to slightly open.
	410						100						
	415	100											
	420												
	425	92			H5		77						
	430	100		W4									222.2-224.4': BASALT. Black to gray basalt, mostly fine grained with plagioclase phenocrysts up to 1-2 mm diameter. Phenocrysts comprise less than 5% of the rock. Slightly Weathered (W3). Oxidation (iron and manganese) limited to fracture surfaces, phenocrysts are soft and discolored to a grayish white color. Hard (H3). Core breaks with heavy hammer blow. Intensely Fractured (FD7). Core recovered in lengths from fragments to 0.3', joint surfaces are mostly smooth and planar to irregular and coated with brownish-red clay. Prior to removal from core barrel (undisturbed) the joints were tight to slightly open.
	435	100											
	440						90						
	445					FD4							
	450	100		W2	H3								224.4-228.1': BASALT. Black to gray basalt, mostly fine grained with plagioclase phenocrysts up to 1-2 mm diameter. Phenocrysts comprise less than 5% of the rock. Slightly Weathered (W3). Oxidation (iron and manganese) limited to fracture surfaces, phenocrysts are soft and discolored to a grayish white color. Hard (H3).. Core breaks with heavy hammer blow. Moderately Fractured (FD5). Core recovered in lengths from 0.4 to
	455	100					98						

GEOLOGIC LOG OF DRILL HOLE NO. DH-04-1

FEATURE: Black Rock Alternate Damsite
LOCATION: North of Washington State Highway 24
BEGUN: 1/30/04 FINISHED: 3/31/04
DEPTH AND ELEV OF WATER
LEVEL AND DATE MEASURED: 190.9 (1156.45) 3/31/04

PROJECT: Yakima R. Basin Water Storage Feas. Study
COORDINATES: N 439,357.5 E 1,790,476.4
TOTAL DEPTH: 562.3
DEPTH TO BEDROCK: 145.3

STATE: Washington
GROUND ELEVATION: 1347.4
ANGLE FROM HORIZONTAL: AZIMUTH:
HOLE LOGGED BY: Stelma/McAffee/Lyon
REVIEWED BY: R. A. Link

NOTES	DEPTH	% RECOVERY	SPT	ENGINEERING PROPERTIES: WEATHERING	HARDNESS	FRACTURE DENSITY	RQD	FIELD CLASSIFICATION	LAB CLASSIFICATION	GEOLOGIC UNIT	GRAPHIC	HOLE COMPLETION	CLASSIFICATION AND PHYSICAL CONDITION
	460	100					100						1.1', mostly in lengths of 0.8', the joint surfaces are mostly smooth and planar to irregular. Numerous joints were weakly rehealed (silica), but separated upon handling. Prior to removal from core barrel (undisturbed) the joints were tight to slightly open.
	465	97					35						
	470	100		W7	H5	FD3	79	Siltstone		Tm			228.1-242.3': BASALT. Black to gray basalt, mostly fine grained with plagioclase phenocrysts up to 1-2 mm diameter. Phenocrysts comprise less than 5% of the rock. Slightly Weathered (W3). Oxidation (iron and manganese) limited to fracture surfaces, phenocrysts are soft and discolored to a grayish white color. Hard (H3). Core breaks with heavy hammer blow. Intensely to Moderately Fractured (FD6). Core recovered in lengths from fragments to 0.6', joint surfaces are mostly smooth and planar to irregular. Numerous joints were weakly rehealed (silica), but separated upon handling, Prominent subvertical joints were observed from 228.1-232.2' and 232.3-236.9'. Prior to removal from core barrel (undisturbed) the joints were tight to slightly open.
	475	100											
	480												
	485	100											
	490	89		W9	H6	FD9	0	SP					242.3-251.4': BASALT (Poor Recovery). Black to gray basalt, mostly fine grained with plagioclase phenocrysts up to 1-2 mm diameter. Phenocrysts comprise less than 5% of the rock. Slightly Weathered (W3). Oxidation (iron and manganese) limited to fracture surfaces, phenocrysts are soft and discolored to a grayish white color. Hard (H3). Core breaks with heavy hammer blow. Very Intensely Fractured (FD9). Core recovered in lengths from fragments to 0.4', mostly fragments, the joint surfaces are mostly smooth and planar to irregular.
	495												
	500	82											
	505			W7	H5	FD3	100	Siltstone					251.4-254.8': BASALT. Black to gray basalt, mostly fine-grained with plagioclase phenocrysts up to 1-2 mm diameter. Phenocrysts comprise less than 5% of the rock. Fairly sharp contact with underlying claystone. Slightly Weathered (W3). Oxidation (iron and manganese) limited to fracture surfaces, phenocrysts are soft and discolored to a grayish white color. Hard (H3). Core breaks with heavy hammer blow. Intensely to Moderately Fractured (FD6). Core recovered in lengths from fragments to 0.9', mostly less than 0.4', the joint surfaces are mostly smooth and planar to irregular. Numerous joints were weakly rehealed (silica), but separated upon handling. Prior to removal from core barrel (undisturbed) the joints were tight to slightly open.
	510	99											
	515							Sandstone					
	520												
	525	100											
	530							Siltstone					254.8-277.1': **SELAH INTERBED (Ts)** of the Miocene Ellensburg Formation. Reddish orange, black to gray, moderately soft tuffaceous siltstone and claystone. Descriptions are based on HQ-size core samples.
	535	100											
	540							Claystone					255.8-258.2': TUFFACEOUS CLAYSTONE. Fine to medium grained, reddish orange to greenish yellow, heterogenous, well indurated clay-size to medium sand-sized lithic fragments, pumice, ash and chert. Intensely Weathered (W7). Material has been thermally altered and oxidized. Moderately Soft (H5). Core scratches with light to moderate knife pressure. Slightly Fractured (FD3). Core recovered mostly in lengths from 1.0 to 3.0'.
	545	100				FD5	58	Siltstone					
	550					FD6							
	555	100					48	Claystone					258.2-263.0': TUFFACEOUS SILTSTONE AND SANDSTONE . Fine to medium grained, black, heterogenous, well indurated silt-size to medium sand-sized lithic fragments, pumice, ash and chert. Intensely Weathered (W7). Material has been thermally altered and oxided. Soft (H6). Core breaks with light manual pressure. Intensely to Moderately Fractured (FD6). Core recovered in lengths from fragments to 0.8", and mostly in lengths less than 0.4'.
		90											
	560	100		W3	H4		47	Basalt		Tpr			
								BOTTOM OF HOLE					263.0-273.6': TUFFACEOUS SILTSTONE AND SANDSTONE. Fine to medium grained, white to light brown and gray (mottled), heterogenous, well indurated silt-size to coarse sand-sized (5 mm) lithic fragments, pumice, ash and chert. Intensely Weathered (W7). Abundant calcium carbonate nodules and stringers

GEOLOGIC LOG OF DRILL HOLE NO. DH-04-1

FEATURE: Black Rock Alternate Damsite
LOCATION: North of Washington State Highway 24
BEGUN: 1/30/04 FINISHED: 3/31/04
DEPTH AND ELEV OF WATER
LEVEL AND DATE MEASURED: 190.9 (1156.45) 3/31/04

PROJECT: Yakima R. Basin Water Storage Feas. Study
COORDINATES: N 439,357.5 E 1,790,476.4
TOTAL DEPTH: 562.3
DEPTH TO BEDROCK: 145.3

STATE: Washington
GROUND ELEVATION: 1347.4
ANGLE FROM HORIZONTAL: AZIMUTH:
HOLE LOGGED BY: Stelma/McAffee/Lyon
REVIEWED BY: R. A. Link

NOTES	DEPTH	% RECOVERY	SPT	ENGINEERING PROPERTIES: WEATHERING	HARDNESS	FRACTURE DENSITY	RQD	FIELD CLASSIFICATION	LAB CLASSIFICATION	GEOLOGIC UNIT	GRAPHIC	HOLE COMPLETION	CLASSIFICATION AND PHYSICAL CONDITION

present due to extensive leaching and solutioning of rock (strong reaction with HCl). Moderately Hard (H4). Core breaks with heavy manual pressure. Slightly Fractured (FD3). Core recovered mostly in lengths from 1.0 to 2.0'. Possible brecciated zone. Slickensides (striations) noted on joint surfaces at 271.6', 271.9', 272.5', 272.7' 272.8' and 273.0'.

273.6-277.1': TUFFACEOUS CLAYEY GRAVEL WITH SAND (GC)s. About 70% fine, moderately soft, angular sand; about 20% fines with medium plasticity; about 10% fine, moderately soft, angular gravel; moist, brown to dark brown, clasts composed of chert and claystone. Slickensides (striations) noted on joint surface at 273.8'.

279.4-467.0': **ESQUATZEL/UMATILLA UNDIFFERENTIATED MEMBERS (Teq/Tum)** of the Saddle Mountains Basalt Formation, Miocene Columbia River Basalt Group (CRBG. Black to gray, hard, mostly fine grained dense basalt. Descriptions are based on HQ-size core samples.

276.0-277.1': BASALT. Black to gray, mostly fine grained, dense basalt. Fairly sharp contact with overlying sediment. Moderately Weathered (W3). Extensive oxidation (iron and manganese) and clay deposits on fracture surfaces, body of rock is weakened by weathering. Moderately Hard (H4). Core breaks with moderate hammer blow. Intensely Fractured (FD7). Core recovered in lengths from fragments to 1.0', mostly less than 0.3', the joint surfaces are mostly smooth and planar to irregular.

277.1-295.9': BASALT. Black to gray, mostly fine grained, dense basalt. Slightly vesicular from 287.5-289.7. Slightly Weathered (W3). Oxidation (iron and manganese) and coatings limited to fracture surfaces. Hard (H3). Core breaks with heavy hammer blow. Intensely to Moderately Fractured (FD6). Core recovered in lengths from fragments to 0.9, and mostly in lengths greater than 0.5', the joint surfaces are mostly smooth and planar to irregular. Prominent vertical joint and associated fracture zone from 290.2-293.0'. Numerous joints were weakly rehealed (silica), but separated upon handling. Prior to removal from core barrel (undisturbed) the joints were tight to slightly open. Slickensides (poorly defined striations) noted on subvertical joint surface from 287.5-289.7', surface is extensively oxidized with abundant clayey material.

Magnetic Polarity on Sample at 285.5': Normal.

295.9-303.2': BASALT. Black to gray, mostly fine grained, dense basalt. Slightly Weathered (W3). Extensive oxidation (iron and manganese) and greenish yellow clay coatings on fracture surfaces. Hard (H3). Core breaks with heavy hammer blow. Very Intensely Fractured (FD9). Core recovered mostly as fragments, fracture surfaces are mostly smooth and planar to irregula . Prior to removal from core barrel (undisturbed) the joints were tight to slightly open.

303.2-322.6': BASALT. Black to gray, mostly fine grained, dense basalt. Fresh to Slightly Weathered (W2). Minor oxidation (iron and manganese) limited to fracture surfaces. Hard (H3). Core breaks with heavy hammer blow. Slightly to Very Slightly Fractured (FD2). Core recovered in lengths ranging from 0.4' to 4.0', mostly in lengths greater than 3.0', fracture surfaces are mostly smooth and irregular to smooth and planar. Prior to removal from core barrel (undisturbed) the joints were mostly tight.

322.6-326.7': BASALT. Black to gray, mostly fine grained, dense basalt. Slightly Weathered (W3). Oxidation (iron and manganese) limited to fracture surfaces. Hard (H3). Core breaks with heavy hammer blow. Intensely Fractured (FD7). Core recovered in lengths from fragments to 1.7', mostly in lengths less

GEOLOGIC LOG OF DRILL HOLE NO. DH-04-1

FEATURE: Black Rock Alternate Damsite
LOCATION: North of Washington State Highway 24
BEGUN: 1/30/04 FINISHED: 3/31/04
DEPTH AND ELEV OF WATER
LEVEL AND DATE MEASURED: 190.9 (1156.45) 3/31/04

PROJECT: Yakima R. Basin Water Storage Feas. Study
COORDINATES: N 439,357.5 E 1,790,476.4
TOTAL DEPTH: 562.3
DEPTH TO BEDROCK: 145.3

STATE: Washington
GROUND ELEVATION: 1347.4
ANGLE FROM HORIZONTAL: AZIMUTH:
HOLE LOGGED BY: Stelma/McAffee/Lyon
REVIEWED BY: R. A. Link

NOTES	DEPTH	% RECOVERY	SPT	ENGINEERING PROPERTIES: WEATHERING	HARDNESS	FRACTURE DENSITY	RQD	FIELD CLASSIFICATION	LAB CLASSIFICATION	GEOLOGIC UNIT	GRAPHIC	HOLE COMPLETION	CLASSIFICATION AND PHYSICAL CONDITION

than 0.3', the joint surfaces are mostly smooth and planar to irregular to rough and irregular. A single subvertical joint and associated horizontal joints were observed through the entire interval. Prior to removal from core barrel (undisturbed) the joints were generally tight to slightly open.

326.7-341.1': BASALT. Black to gray, mostly fine grained, dense basalt. Fresh to Slightly Weathered (W2). Minor oxidation (iron and manganese) limited to fracture surfaces. Hard (H3). Core breaks with heavy hammer blow. Slightly Fractured (FD3). Core recovered in lengths ranging from 0.5' to 2.4', mostly in lengths between 1.0 and 1.5', fracture surfaces are mostly smooth and planar to smooth and irregular. Prior to removal from core barrel (undisturbed) the joints were mostly tight.

341.1-349.9': BASALT. Black to gray, mostly fine grained, dense basalt. Slightly Weathered (W3). Oxidation (iron and manganese) limited to fracture surfaces. Hard (H3). Core breaks with heavy hammer blow. Intensely Fractured (FD7). Core recovered in lengths from fragments to 1.7', mostly in lengths less than 0.3', the joint surfaces are mostly smooth and planar to irregular to rough and irregular. A single subvertical joint and associated horizontal joints were observed through the entire interval. Prior to removal from core barrel (undisturbed) the joints were generally tight to slightly open.

349.9-358.2': BASALT. Black to dark green, mostly fine grained, dense basalt. Slightly Weathered (W3). Oxidation (iron and manganese) generally limited to fracture surfaces. Hard (H3). Core breaks with heavy hammer blow. Moderately to Slightly Fractured (FD4). Core recovered in lengths from fragments to 1.6', mostly in lengths around 0.8', the joint surfaces are mostly smooth and planar to irregular to rough and irregular. A single subvertical joint and associated horizontal joints were observed through most of the interval. Prior to removal from core barrel (undisturbed) the joints were generally tight to slightly open.

358.2-421.5': BASALT. Black to gray, mostly fine grained, dense basalt. Slightly Weathered (W3). Oxidation (iron and manganese) generally limited to fracture surfaces. Hard (H3). Core breaks with heavy hammer blow. Slightly Fractured (FD3). Core recovered in lengths from 0.1' to 2.8', mostly in lengths about 1.4', the joint surfaces are mostly smooth and planar to irregular to rough and irregular. Prior to removal from core barrel (undisturbed) the joints were generally tight to slightly open.

Magnetic Polarity on Sample at 360.3': Normal.

Magnetic Polarity on Sample at 384.7': Normal.

421.5-426.6': BASALT. Black to gray, fine grained, slightly to moderately vesicular basalt. Slightly Weathered (W3). Oxidation (iron and manganese) generally limited to fracture surfaces. Hard (H5). Core breaks with moderate to heavy hammer blow. Moderately to Slightly Fractured (FD4). Core recovered in lengths from fragments to 0.9', mostly in lengths around 0.4', the joint surfaces are mostly smooth and planar to irregular to rough and irregular.

426.6-431.5': BASALT (FLOW BRECCIA). Dark green to black, fine grained, moderately to strongly vesicular basalt. Moderately to Slightly Weathered (W4). Numerous indurated clay and silty clay seams, body of rock is slightly weathered. Hard (H5). Core breaks with moderate to heavy hammer blow. Moderately to Slightly Fractured (FD4). Core recovered in lengths from 0.2' to 1.9', mostly in lengths about 0.4', the joint surfaces are mostly rough and irregular.

GEOLOGIC LOG OF DRILL HOLE NO. DH-04-1

FEATURE: Black Rock Alternate Damsite
LOCATION: North of Washington State Highway 24
BEGUN: 1/30/04 FINISHED: 3/31/04
DEPTH AND ELEV OF WATER
LEVEL AND DATE MEASURED: 190.9 (1156.45) 3/31/04

PROJECT: Yakima R. Basin Water Storage Feas. Study
COORDINATES: N 439,357.5 E 1,790,476.4
TOTAL DEPTH: 562.3
DEPTH TO BEDROCK: 145.3

STATE: Washington
GROUND ELEVATION: 1347.4
ANGLE FROM HORIZONTAL: AZIMUTH:
HOLE LOGGED BY: Stelma/McAffee/Lyon
REVIEWED BY: R. A. Link

NOTES	DEPTH	% RECOVERY	SPT	ENGINEERING PROPERTIES: WEATHERING	HARDNESS	FRACTURE DENSITY	RQD	FIELD CLASSIFICATION	LAB CLASSIFICATION	GEOLOGIC UNIT	GRAPHIC	HOLE COMPLETION	CLASSIFICATION AND PHYSICAL CONDITION

431.5-461.5': BASALT. Black to gray, mostly fine grained, dense to very slightly vesicular basalt. Slightly Weathered (W2). Oxidation (iron and manganese) generally limited to fracture surfaces, some vesicles infilled with calcium carbonate (strong reaction with HCl). Hard (H3). Core breaks with heavy hammer blow. Moderately to Slightly Fractured (FD4). Core recovered in lengths from fragments to 0.1' to 2.8', mostly in lengths about 1.4', the joint surfaces are mostly smooth and planar, with scattered irregular to rough and irregular surfaces.

Magnetic Polarity on Sample at 455.5': Normal.

457.0-459.2': LEAN CLAY. (Inclusion of underlying Mabton Interbed). About 100% fines with medium plasticity, slow dilatancey and medium toughness, green, moist.

467.0-555.8': **MABTON INTERBED (Tm)** of the Miocene Ellensburg Formation. Light green to to dark brown, moderately soft, tuffaceous siltstone, sandstone and claystone. Descriptions are based on HQ-size core samples.

467.0-490.0': SILTSTONE. Fine grained, light green to gray, homogeneous, well indurated silt-size to some medium sand-sized fragments with abundant mafic and micaceous material. Intensely Weathered (W7). Material is partially altered to clay. Moderately Soft (H5). Core scratches with light to moderate knife pressure. Slightly Fractured (FD3). Core recovered mostly in lengths from 1.0 to 3.0'.

490.0-502.4': POORLY GRADED SAND (SP). About 100% predominantly medium, hard, subangular to angular sand; dry to moist, gray with reddish brown lenses, abundant iron oxide.

502.4-510.9': SILTSTONE. Fine grained, light green to tan, homogeneous, well indurated silt-size material. Intensely Weathered (W7). Some minerals altered to clay due to extensive leaching and solutioning of rock. Moderately Soft (H5). Core scratches with light to moderate knife pressure. Slightly Fractured (FD3). Core recovered mostly in lengths ranging from 1.0 to 3.0'.

510.9-525.8': SANDSTONE. Fine to medium grained, green to black, homogeneous, well indurated silt-size to medium sand-sized fragments with abundant mafic and micaceous material. Intensely Weathered (W7). Some of the minerals are altered to clay due to extensive leaching and solutioning of rock. Moderately Soft (H5). Core scratches with light to moderate knife pressure. Slightly Fractured (FD3). Core recovered in lengths from 1.0 to 3.0'.

525.8-536.1': SILTSTONE. Fine grained, light green to white, homogeneous, well indurated silt-size material. Intensely Weathered (W7). Some minerals altered to clay due to extensive leaching and solutioning of rock. Moderately Soft (H5). Core scratches with light to moderate knife pressure. Slightly Fractured (FD3). Core recovered mostly in lengths ranging from 0.5 to 5.0'.

536.1-543.9': CLAYSTONE. Fine grained, greenish gray to black, homogeneous, well indurated clay-size material. Intensely Weathered (W7). Sample is mostly clay due to extensive leaching and solutioning of rock. Moderately Soft (H5). Core scratches with light to moderate knife pressure. Slightly Fractured (FD3). Core recovered mostly in lengths ranging from 0.9 to 1.8'.

543.9-549.4': SILTSTONE. Fine grained, mottled dark brown to black, well indurated silt-size material. Abundant organics, wood and coal (lignite) fragments up to 25 mm. Intensely Weathered (W7). Some minerals altered to clay due to due to extensive leaching and solutioning of rock. Moderately Soft (H5). Core

GEOLOGIC LOG OF DRILL HOLE NO. DH-04-1

FEATURE: Black Rock Alternate Damsite
LOCATION: North of Washington State Highway 24
BEGUN: 1/30/04 FINISHED: 3/31/04
DEPTH AND ELEV OF WATER
LEVEL AND DATE MEASURED: 190.9 (1156.45) 3/31/04

PROJECT: Yakima R. Basin Water Storage Feas. Study
COORDINATES: N 439,357.5 E 1,790,476.4
TOTAL DEPTH: 562.3
DEPTH TO BEDROCK: 145.3

STATE: Washington
GROUND ELEVATION: 1347.4
ANGLE FROM HORIZONTAL: AZIMUTH:
HOLE LOGGED BY: Stelma/McAffee/Lyon
REVIEWED BY: R. A. Link

NOTES	DEPTH	% RECOVERY	SPT	ENGINEERING PROPERTIES: WEATHERING	HARDNESS	FRACTURE DENSITY	RQD	FIELD CLASSIFICATION	LAB CLASSIFICATION	GEOLOGIC UNIT	GRAPHIC	HOLE COMPLETION	CLASSIFICATION AND PHYSICAL CONDITION

scratches with light to moderate knife pressure. Moderately Fractured (FD5). Core recovered mostly in lengths ranging from 0.4 to 1.0'. Slickensides (striations) noted on subvertical joint surfaces at 543.9', 546.4', 546.6' and at 549.4'.

549.4-555.8': CLAYSTONE. Fine grained, mottled greenish brown, well indurated clay-size material. Trace of organics, wood fragments up to 10 mm. Intensely Weathered (W7). Sample is mostly clay due to extensive leaching and solutioning of rock. Moderately Soft (H5). Core scratches with light to moderate knife pressure. Slightly Fractured (FD3). Core recovered mostly in lengths ranging from 0.9 to 1.8'. Slickensides (striations) noted on joint surfaces at 550.5', 553.2', 553.3', 554.2' and at 555.8'.

555.8-562.3': **PRIEST RAPIDS MEMBER (Tpr)** of the Wanapum Basalt Formation, Miocene Columbia River Basalt Group (CRB). Black to gray, hard, fine grained to porphyritic, vesicular basalt. Descriptions are based on HQ-size core samples.

556.0-562.3': BASALT. Black to gray moderately vesicular basalt, mostly fine grained with abundant elongate and angular plagioclase phenocrysts up to 1 mm diameter. Phenocrysts comprise about 10% of the rock. Fairly sharp contact with overlying claystone. Slightly Weathered (W3). Oxidation (iron and manganese) limited to fracture surfaces; vesicles are infilled with bluish silt and clay; abundant iron pyrite noted on fracture surface and within vesicles; all phenocrysts are discolored to a grayish white color. Hard (H3). Core breaks with moderate hammer blow. Intensely to Moderately Fractured (FD6). Core recovered in lengths from fragments to 0.9', mostly less than 0.4', the joint surfaces are mostly rough and planar to rough and irregular. Prior to removal from core barrel (undisturbed) the joints were moderately open (1 to 3 mm).

Magnetic Polarity on Sample from 560.0-560.7': Reverse.

562.3': BOTTOM OF HOLE


BLACK ROCK DAMSITE
ALTERNATE ALIGNMENT
YAKIMA RIVER BASIN WATER
STORAGE FEASIBILITY STUDY
DH-04-1
FROM 0° to 43°
0° 5°
57
21
178
312
35°
35°
40°
43°


BLACK ROCK DAMSITE
ALTERNATE ALIGNMENT
YAKIMA RIVER BASIN WATER
STORAGE FEASIBILITY STUDY
DH-04-1
FROM 43° to 60°
45°
50°
51°
55°
55°
58°
60°

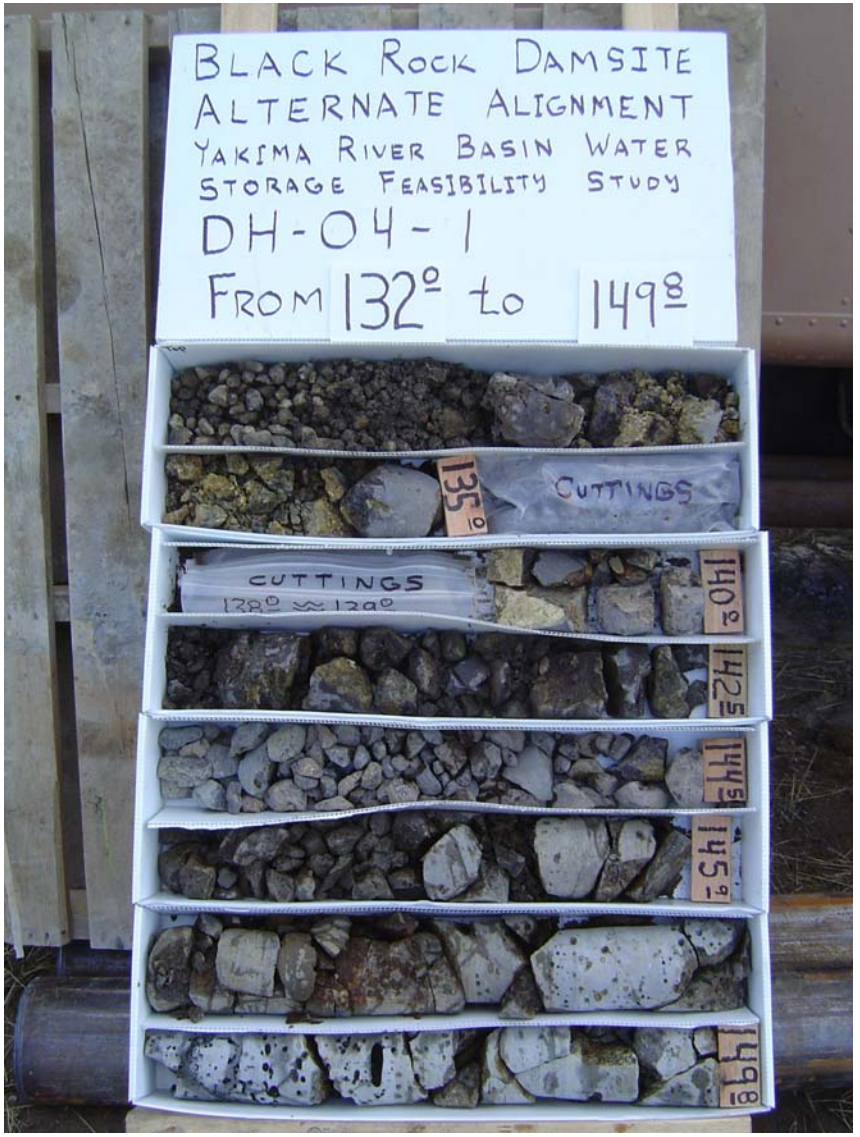

BLACK ROCK DAMSITE
ALTERNATE ALIGNMENT
YAKIMA RIVER BASIN WATER
STORAGE FEASIBILITY STUDY
DH-04-1
FROM 60º to 75º
60°
65°
68'
70°
72'
75°


BLACK ROCK DAMSITE
ALTERNATE ALIGNMENT
YAKIMA RIVER BASIN WATER
STORAGE FEASIBILITY STUDY
DH-04-1
FROM 75º to 85º
78'
80°
81'
85°


ALTERNATE ALIGNMENT
YAKIMA RIVER BASIN WATER
STORAGE FEASIBILITY STUDY
DH-04-1
FROM 85° to 100°
90°
95°
100


BLACK ROCK DAMSITE
ALTERNATE ALIGNMENT
YAKIMA RIVER BASIN WATER
STORAGE FEASIBILITY STUDY
DH-04-1
FROM 100° to 115°
100°
105°
110
115°


BLACK ROCK DAMSITE
ALTERNATE ALIGNMENT
YAKIMA RIVER BASIN WATER
STORAGE FEASIBILITY STUDY
DH-04-1
FROM 115' to 132'
119.5
120'
125'
129
130
132


BLACK ROCK DAMSITE
ALTERNATE ALIGNMENT
YAKIMA RIVER BASIN WATER
STORAGE FEASIBILITY STUDY
DH-04-1
FROM 132' to 149.8'
135'
CUTTINGS
CUTTINGS
138' ≈ 139'
140'
142.5'
144.5'
145.5'
149.8'


BLACK ROCK DAMSITE
ALTERNATE ALIGNMENT
YAKIMA RIVER BASIN WATER
STORAGE FEASIBILITY STUDY
DH-04-1
FROM 149' TO 166'

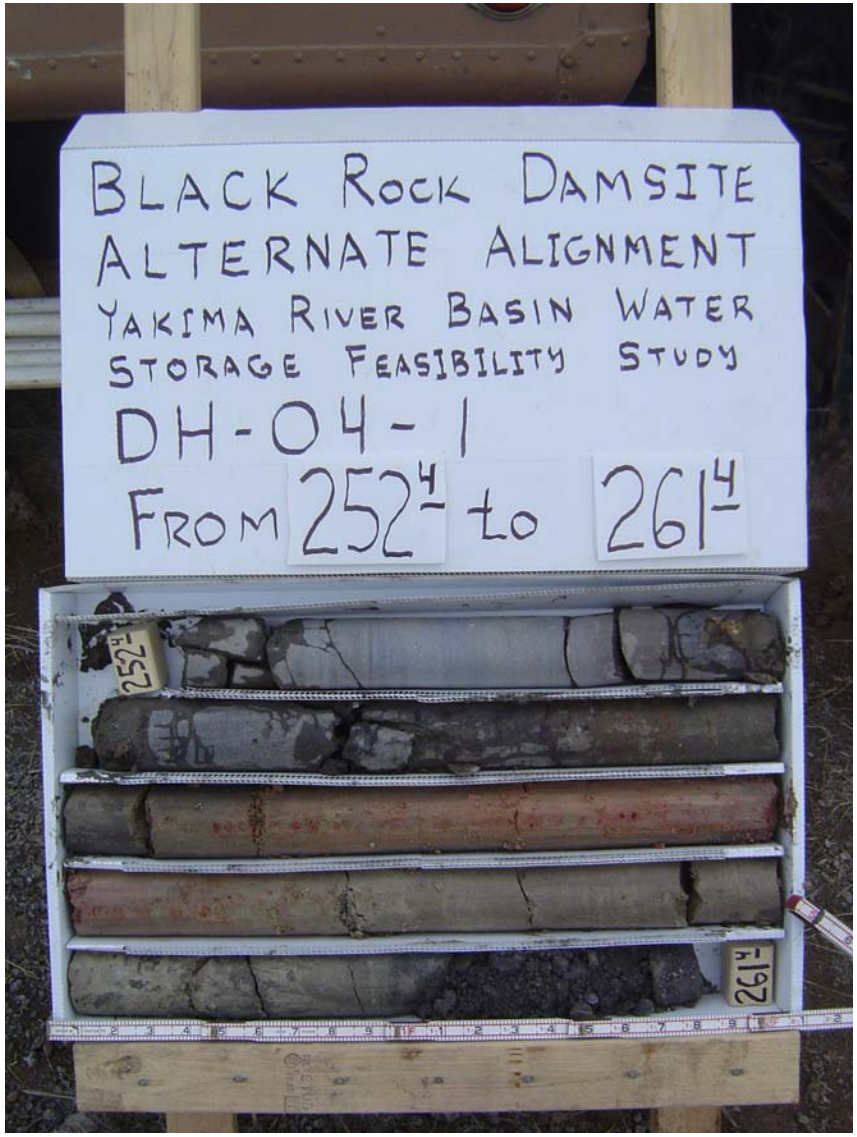

BLACK ROCK DAMSITE
ALTERNATE ALIGNMENT
YAKIMA RIVER BASIN WATER
STORAGE FEASIBILITY STUDY
DH-04-1
FROM 166' TO 183'


BLACK ROCK DAMSITE
ALTERNATE ALIGNMENT
YAKIMA RIVER BASIN WATER
STORAGE FEASIBILITY STUDY
DH-04-1
FROM 183' TO 199 3/4'
183'
191 1/4
199 3/4


BLACK ROCK DAMSITE
ALTERNATE ALIGNMENT
YAKIMA RIVER BASIN WATER
STORAGE FEASIBILITY STUDY
DH-04-1
FROM 199 3/4 TO 215 8/12
201 1/4
208 8/12
211 1/4


BLACK ROCK DAMSITE
ALTERNATE ALIGNMENT
YAKIMA RIVER BASIN WATER
STORAGE FEASIBILITY STUDY
DH-04-1
FROM 215 8 TO 232 2
215 8
216 5
221 4
230'
232 2


BLACK ROCK DAMSITE
ALTERNATE ALIGNMENT
YAKIMA RIVER BASIN WATER
STORAGE FEASIBILITY STUDY
DH-04-1
FROM 232 2 TO 252 4
232 2
238 2
238 9
240 3
241 4
242 3
251 4
252 4


BLACK ROCK DAMSITE
ALTERNATE ALIGNMENT
YAKIMA RIVER BASIN WATER
STORAGE FEASIBILITY STUDY
DH-04-1
FROM 252 4/5 to 261 4/5
252 4/5
261 4/5


BLACK ROCK DAMSITE
ALTERNATE ALIGNMENT
YAKIMA RIVER BASIN WATER
STORAGE FEASIBILITY STUDY
DH-04-1
FROM 261 4/5 to 279 8/5
261 4/5
264 6/5
267 9/5
271 1/5
275 1/5


BLACK ROCK DAMSITE
ALTERNATE ALIGNMENT
YAKIMA RIVER BASIN WATER
STORAGE FEASIBILITY STUDY
DH-04-1
FROM 279 8/10 to 295 9/10

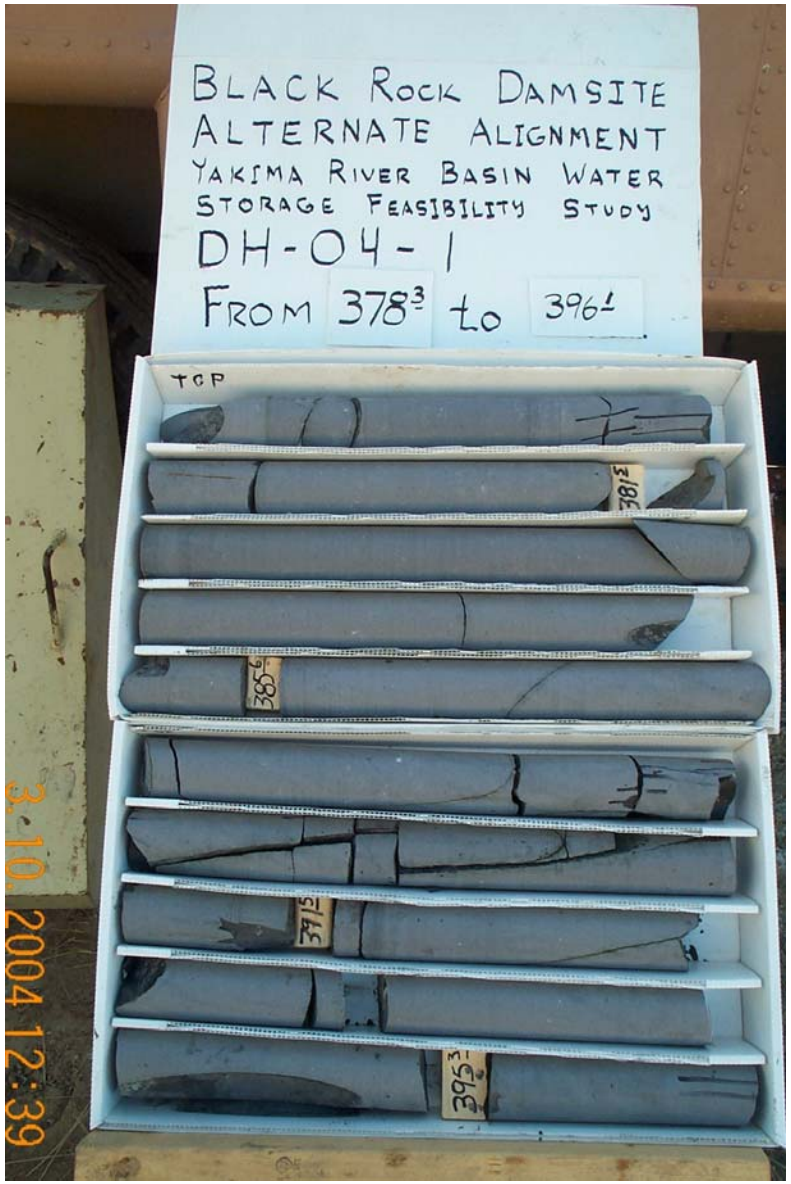

BLACK ROCK DAMSITE
ALTERNATE ALIGNMENT
YAKIMA RIVER BASIN WATER
STORAGE FEASIBILITY STUDY
DH-04-1
FROM 295 9/10 to 310 3/10

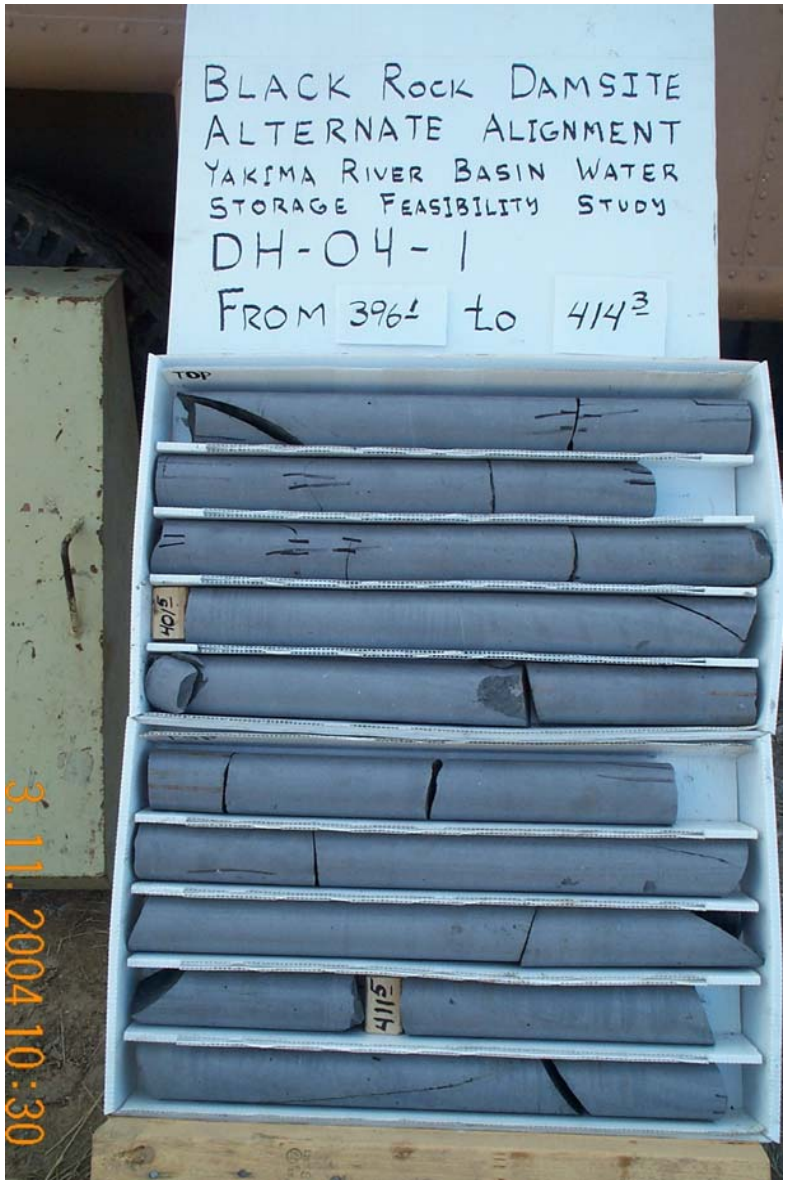

BLACK ROCK DAMSITE
ALTERNATE ALIGNMENT
YAKIMA RIVER BASIN WATER
STORAGE FEASIBILITY STUDY
DH-04-1
FROM 310³ to 326⁷
310³
326⁷


BLACK ROCK DAMSITE
ALTERNATE ALIGNMENT
YAKIMA RIVER BASIN WATER
STORAGE FEASIBILITY STUDY
DH-04-1
FROM 326⁷ to 349⁹
330⁴
335⁹
340³
349⁹


BLACK ROCK DAMSITE
ALTERNATE ALIGNMENT
YAKIMA RIVER BASIN WATER
STORAGE FEASIBILITY STUDY
DH-04-1
FROM 349 9/10 to 360 8/10
TOP
3582
360
3.9.2004 14:53


BLACK ROCK DAMSITE
ALTERNATE ALIGNMENT
YAKIMA RIVER BASIN WATER
STORAGE FEASIBILITY STUDY
DH-04-1
FROM 360 8/10 to 378 3/10
TOP
3715
3615
3.10.2004 09:36


BLACK ROCK DAMSITE
ALTERNATE ALIGNMENT
YAKIMA RIVER BASIN WATER
STORAGE FEASIBILITY STUDY
DH-04-1
FROM 378 3 TO 396 1
TOP
3.10.2004 12:39


BLACK ROCK DAMSITE
ALTERNATE ALIGNMENT
YAKIMA RIVER BASIN WATER
STORAGE FEASIBILITY STUDY
DH-04-1
FROM 396 1 TO 414 3
TOP
3.11.2004 10:30


BLACK ROCK DAMSITE
ALTERNATE ALIGNMENT
YAKIMA RIVER BASIN WATER
STORAGE FEASIBILITY STUDY
DH-04-1
FROM 414.3 to 432.8
TOP
3.12.2004 09:48


BLACK ROCK DAMSITE
ALTERNATE ALIGNMENT
YAKIMA RIVER BASIN WATER
STORAGE FEASIBILITY STUDY
DH-04-1
FROM 432.8 to 450.4
TOP
3.12.2004 10:18


BLACK ROCK DAMSITE
ALTERNATE ALIGNMENT
YAKIMA RIVER BASIN WATER
STORAGE FEASIBILITY STUDY
DH-04-1
FROM 450' to 477'

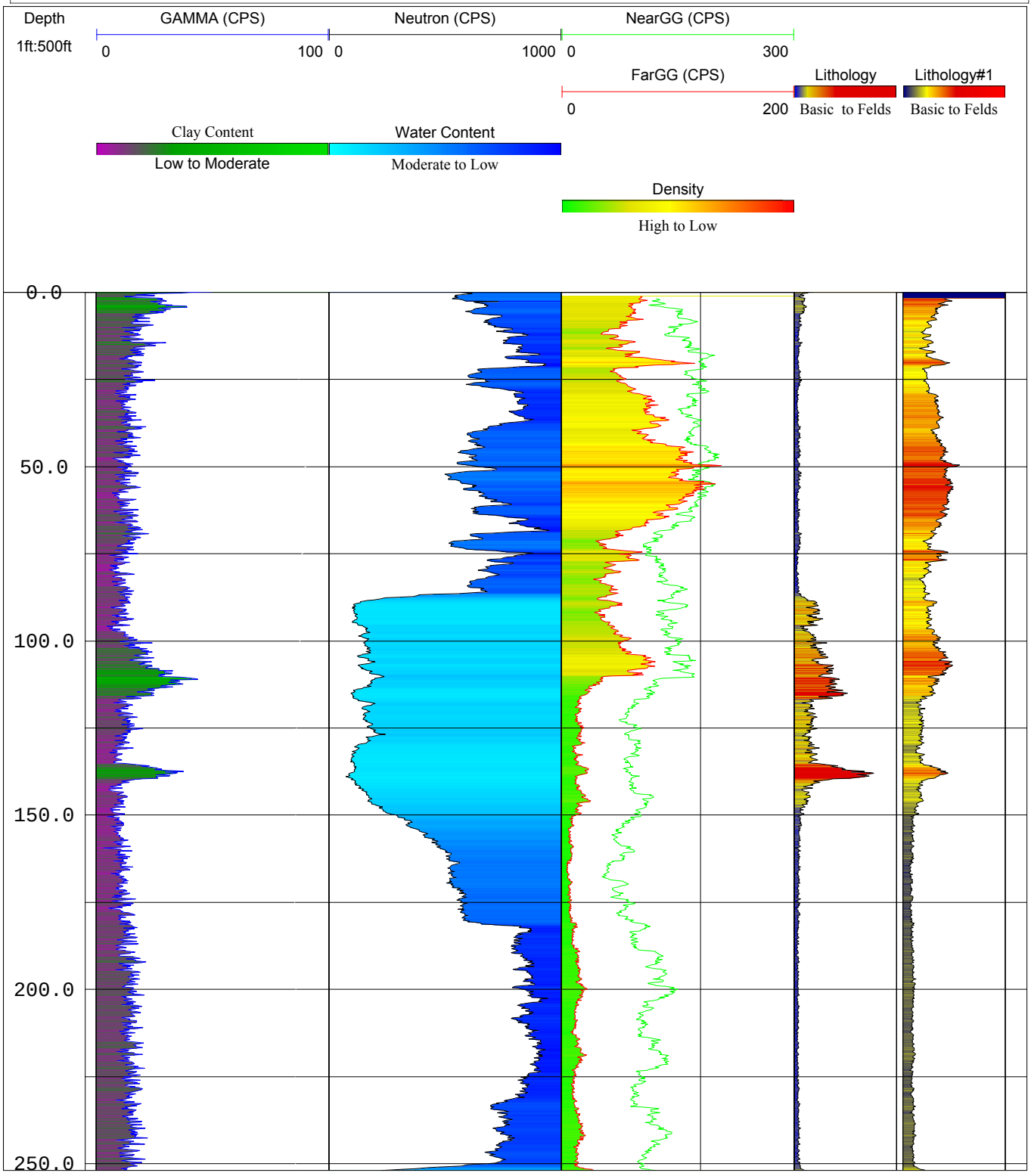

BLACK ROCK DAMSITE
ALTERNATE ALIGNMENT
YAKIMA RIVER BASIN WATER
STORAGE FEASIBILITY STUDY
DH-04-1
FROM 477' to 508'
TOP

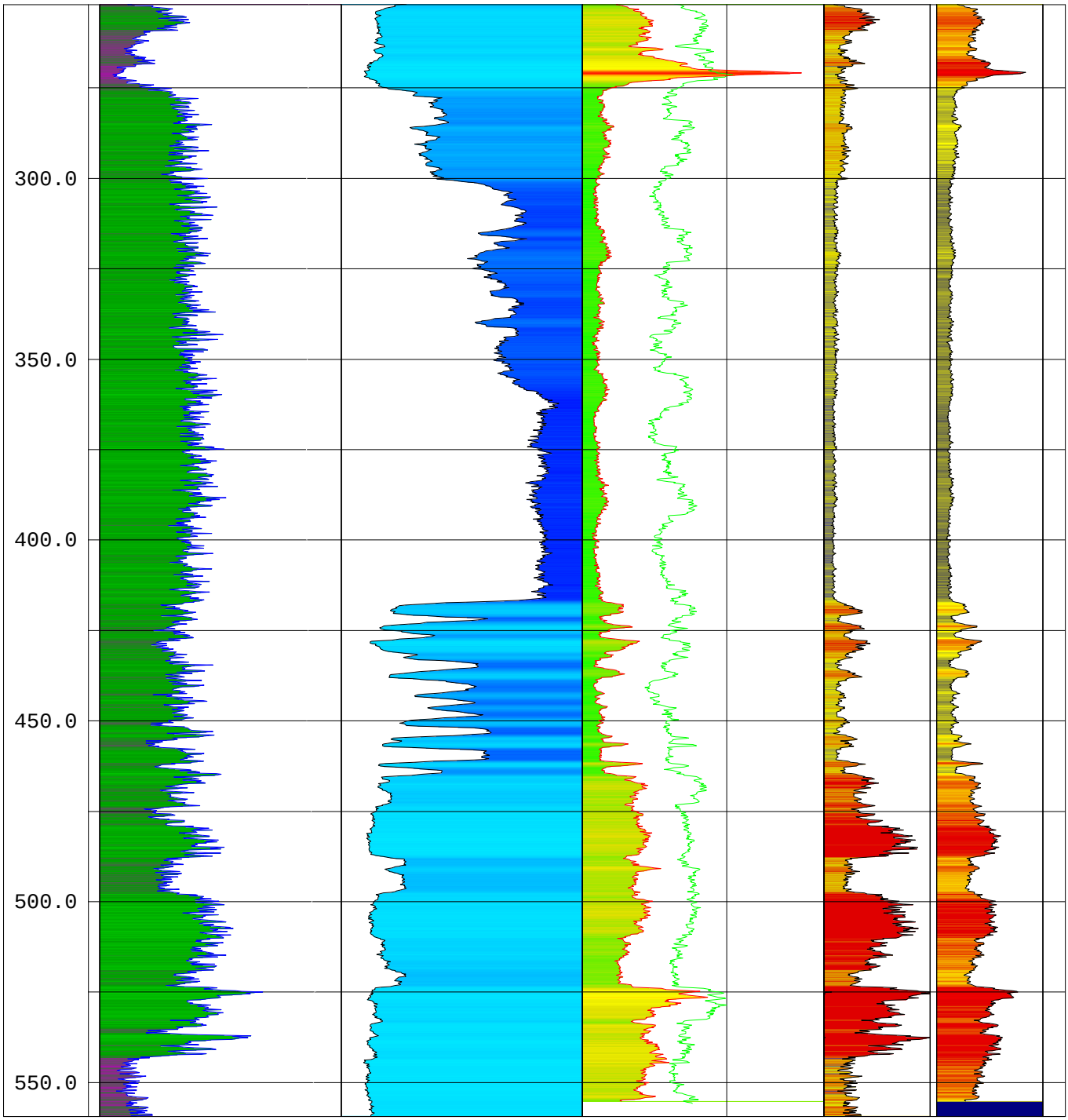

BLACK ROCK DAMSITE
ALTERNATE ALIGNMENT
YAKIMA RIVER BASIN WATER
STORAGE FEASIBILITY STUDY
DH-04-1
FROM 508' to 536'
TOP
TOP


BLACK ROCK DAMSITE
ALTERNATE ALIGNMENT
YAKIMA RIVER BASIN WATER
STORAGE FEASIBILITY STUDY
DH-04-1
FROM 536' to 562.3
TOP
TOP

BUREAU OF RECLAMATION

PROJECT Black Rock HOLE NO. DH04-01




300.0
350.0
400.0
450.0
500.0
550.0

GEOLOGIC LOG OF DRILL HOLE NO. DH-04-2

FEATURE: Black Rock Alternate Damsite
LOCATION: North of Washington State Highway 24
BEGUN: 4/1/04 FINISHED: 6/3/04
DEPTH AND ELEV OF WATER
LEVEL AND DATE MEASURED: 194.1 (1156.46) 6/03/04

PROJECT: Yakima River Basin Water Storage Project
COORDINATES: N 439,391.5 E 1,790,479.2
TOTAL DEPTH: 530.0
DEPTH TO BEDROCK: 144.0

STATE: Washington
GROUND ELEVATION: 1350.6
ANGLE FROM HORIZONTAL: AZIMUTH:
HOLE LOGGED BY: Didricksen/McAffee
REVIEWED BY: R. Link

NOTES	DEPTH	% RECOVERY	SPT	ENGINEERING PROPERTIES: WEATHERING	HARDNESS	FRACTURE DENSITY	RQD	FIELD CLASSIFICATION	LAB CLASSIFICATION	GEOLOGIC UNIT	GRAPHIC	HOLE COMPLETION	CLASSIFICATION AND PHYSICAL CONDITION
All elevations measured from ground surface and are same as driller reported. PURPOSE OF HOLE: Hydro-geologic testing DRILL SETUP: Setup on original ground surface approximately 260 feet north of Washington State Highway 24. DRILLING EQUIPMENT: Ingersoll-Rand T-2 Truck mounted drill. DRILLER: Chris Peterson DRILLING METHODS: **0.0-149.0'** Advanced hole with 7-7/8" rock bit and 8" casing using air as circulating fluid to remove the cuttings from 0-87.0' and 97.0-129.0'. Air and water with foam was used to remove cuttings from 87.0-97.0' and 129.0-149.0'. Constant Head tests were conducted at the intervals of 27.0-31.0', 77.0-81.7' and 117.0-137.0'. **149.0-230.0'** Advanced hole with 5-7/8" downhole hammer to 230.0', using air and water with foam to remove the cuttings from 149.0-230'. Constant Head tests were conducted from 148.0-168.0' and 148.0-230.0'. **230.0-314.0'** Advanced hole with 5-7/8" downhole hammer using air and water with foam to remove the cuttings to 290.0'. Bottom of packer was set at 235.7', and a Slug test was conducted from 236.0-290.0'. Packer removal was difficult due to slight caving from 190.0-200.0'. Hole was cleaned out from 148.0-200.0' with 7-7/8" downhole hammer and stabilizers. Stabilizers came apart at 200.0'. After retrieving stabilizers and downhole hammer, the hole was cleaned out	5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95									Qe Qh Tr			Refer to the log of companion hole DH-04-1 for detailed descriptions of the materials present at this site. All descriptions of material in this log are based on drilling conditions and cuttings returned. 0.0-7.0': **QUATERNARY LOESS DEPOSITS (Qe).** Surficial deposits of silt with lesser amounts of clay, composed primarily of wind-blown silt with small amounts of fine sand and volcanic ash. 0.0-7.0': SILT AND SAND. 7.0-28.0': **QUATERNARY ALLUVIUM DEPOSITS (Qh).** Undifferentiated medium to coarse-grained sand with fines, gravels, cobbles and boulders composed primarily of basaltic detritus from local sources. 7.0-28.0': SILT, SAND, AND GRAVEL. 28.0-87.0': **TERTIARY RINGOLD FORMATION (Tr).** Composed of fluvio lacustrine sand, silt and clay, with cobbles and gravels in a matrix of coarse to fine sand and fines near the middle and base of the unit. 28.0-40.0': SILT, SAND, AND GRAVEL. 40.0-70.0': SILT SAND AND CLAY. 70.0-82.0': SILT, SAND, AND GRAVEL. 82.0-87.0': SILT, SAND, GRAVEL, AND COBBLES. 87.0-144.0': **TERTIARY RATTLESNAKE RIDGE MEMBER (Trr) AND INVASIVE FLOW TOP (PEPERITE) CONSISTING OF SELAH INTERBED (Ts) UNDIFFERENTIATED MEMBERS** of the Miocene Ellensburg Formation. The upper section is comprised of unconsolidated gravel and sand with silt and clay, and the lower section is comprised of pumicite material rafted to the top of the Pomona Basalt, composed of tuffaceous clay, silt, sand and gravel. 87.0-97.0': SILT AND CLAY. 97.0-119.0': SILT AND SAND. 119.0-129.0': CLAY. 129.0-132.0': CLAY, SAND, AND GRAVELS. 132.0-137.0': CLAY, SAND, AND GRAVELS. 137.0-144.0': SAND, GRAVELS AND COBBLES. 144.0-249.0': **POMONA MEMBER (Tp)** of the Saddle Mountains Basalt Formation, Miocene Columbia River Basalt Group (CRBG). Black to gray, hard, mostly fine grained, dense basalt with plagioclase phenocrysts comprising less than 5% of the rock. 144.0-249.0': BASALT.

COMMENTS: Samples were logged in the field using Designation USBR 5005-86, "Procedures for Determining Unified Soil Classification (Visual Method)."

Center column descriptors are defined in the Reclamation Engineering Geology Field Manual, Volume 1, Second Edition, distributed February 1999..

Cs = Casing Sz = Size of Casing I.D. = Inside Diameter O.D. = Outside diameter

Geologic unit descriptions and stratigraphy based partially on consulting discussions with Dr. Bentley and geologic interpretations presented in the following reports:

"Black Rock Reservoir Study, Initial Geotechnical Investigation, Prepared for Benton County Sustainable Development by Washington Infrastructures Services, Inc., Dated January 2003.

"Geologic Investigation Black Rock Dam, Alternate Dam Site, Yakima County, Washington, Prepared for U.S. Bureau of Reclamation by Columbia Geotechnical Associates, Inc., Dated February 12, 2004."

GEOLOGIC LOG OF DRILL HOLE NO. DH-04-2

FEATURE: Black Rock Alternate Damsite
PROJECT: Yakima River Basin Water Storage Project
STATE: Washington
LOCATION: North of Washington State Highway 24
COORDINATES: N 439,391.5 E 1,790,479.2
GROUND ELEVATION: 1350.6
BEGUN: 4/1/04 FINISHED: 6/3/04
TOTAL DEPTH: 530.0
ANGLE FROM HORIZONTAL: AZIMUTH:
DEPTH AND ELEV OF WATER
DEPTH TO BEDROCK: 144.0
HOLE LOGGED BY: Didricksen/McAffee
LEVEL AND DATE MEASURED: 194.1 (1156.46) 6/03/04
REVIEWED BY: R. Link

NOTES	DEPTH	% RECOVERY	SPT	ENGINEERING PROPERTIES: WEATHERING	HARDNESS	FRACTURE DENSITY	RQD	FIELD CLASSIFICATION	LAB CLASSIFICATION	GEOLOGIC UNIT	GRAPHIC	HOLE COMPLETION	CLASSIFICATION AND PHYSICAL CONDITION
with 7-7/8 downhole hammer to 215.0', and 5-7/8" downhole hammer 314.0', using air and water with foam to remove the cuttings. Pump and packer were set at 235.7', and a constant rate pump test was conducted from 236.0-273.0'. Following the test, the hole had caved from 270.0-285.0'. Hole was cleaned out with 7-7/8" downhole hammer using air and water with foam to remove cuttings. Cut slots in 6" casing with plasma cutter and began installing in hole, but could not get it to bottom due to caving. Casing was removed and hole was cleaned with a 7-7/8" tri-cone rockbit to 291.6'. 6" casing was cleaned out with a 5-7/8" rockbit and advanced with a casing hammer to 314.0'. Slotted section is 254.0-294.0'. Pump was set at 245.0', and a step test, pump/constant rate, and slug tests were conducted from 254.0-294.0'. **314.0-405.0'**: Advanced hole with 5-7/8" downhole hammer using air to remove to cuttings to 405.0'. Top of packer was set at depths 362.0' and 372.0', but would not seal. Packer sealed with the top at 352.0', and slug test were conducted at 356.0-405.0' and 381.0-405.0'. **405.0-530.0'**: Advanced hole with 5-7/8" downhole hammer using air to remove cuttings. Encountered heaving sand at 515.0-520.0'. Installed 3" PVC screen and riser to stabalize hole before conducting hydro tests. 8" casing broke while extracting, left in hole from 103.0-143.0'. An airlift/constant drawdown test was conducted in the Mabton unit, and pneumatic slug test were conducted in DH-04-2 and DH-04-1. DRILLING CONDITIONS: **0.0-7.0'**: Fast and smooth. **7.0-70.0'**: Slow to fast and moderately rough. **70.0-87.0'**: Slow and rough. **87.0-129.0'**: Moderately fast and smooth. **129.0-168.0'**: Moderately slow and rough. **168.0-245.0'**: slow and rough to smooth. Caving was noted at depths of	105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195 200 205 210 215									Trr/Ts Tp			249.0-280.0': **SELAH INTERBED (Ts)** of the Miocene Ellensburg Formation. 249.0-280.0': SAND AND GRAVELS. 280.0-466.0': **ESQUATZEL/UMATILLA UNDIFFERENTIATED MEMBERS (Teq/Tum)** of the Saddle Mountains Basalt Formation, Miocene Columbia River Basalt Group (CRBG). Black to gray, hard, mostly fine grained dense basalt. 280.0-466.0': BASALT. 466.0-530.0': **MABTON INTERBED (Tm)** of the Miocene Ellensburg Formation. Light green to to dark brown, tuffaceous siltstone and sandstone. 466.0-515.0': SANDSTONE AND SILT STONE. 515.0-520.0': SAND. 520.0-530.0': SAND AND CLAY.

GEOLOGIC LOG OF DRILL HOLE NO. DH-04-2

FEATURE: Black Rock Alternate Damsite
LOCATION: North of Washington State Highway 24
BEGUN: 4/1/04 FINISHED: 6/3/04
DEPTH AND ELEV OF WATER
LEVEL AND DATE MEASURED: 194.1 (1156.46) 6/03/04

PROJECT: Yakima River Basin Water Storage Project
COORDINATES: N 439,391.5 E 1,790,479.2
TOTAL DEPTH: 530.0
DEPTH TO BEDROCK: 144.0

STATE: Washington
GROUND ELEVATION: 1350.6
ANGLE FROM HORIZONTAL: AZIMUTH:
HOLE LOGGED BY: Didricksen/McAffee
REVIEWED BY: R. Link

NOTES

176.0', 190.0'- 200.0', and 240.0'
245.0-249.0': Slow and rough, blocking.
249.0-285.0': Moderately slow and rough. Caving was noted at depths of 270.0'-285.0'
285.0-466.0': Slow and moderately rough.
466.0-515.0': Moderately fast and smooth.
515.0-530.0': Fast and smooth.

CASING RECORD:

Date	Sz	Hole	Cs Depth
4/1	8"	7.0'	7.0'
4/2	8"	31.0'	27.0'
4/3	8"	82.0'	77.0'
4/5	8"	97.0'	97.0'
4/6	8"	137.0'	227.0'
4/7	8"	165.0'	148.0'
4/8	8"	200.0'	148.0'
4/9	8"	230.0'	148.0'
4/10	8"	290.0'	148.0'
4/23	8"	314.0'	148.0'
5/11	6"	314.0'	314.0'
5/17	6"	374.0'	314.0'
5/18	6"	405.0'	314.0'
5/20	6"	434.0'	314.0'
5/21	6"	530.0'	314.0'

FLUID COLOR:
0.0-31.0': Brown
31.0-40.0': Tan
40.0-82.0': Reddish brown
82.0-119.0': Brown
119.0-129.0': Gray
129.0-137.0': Brown
137.0-144.0': Gray
144.0-249.0': Black
249.0-290.0': Brown
290.0-314.0': Gray
314.0-374.0': Gray
374.0-405.0': Not reported
405.0-466.0': Gray
466.0-515.0': Light brown
151.0-520.0': White
520.0-530.0': Green

FLUID RETURN:
N/A

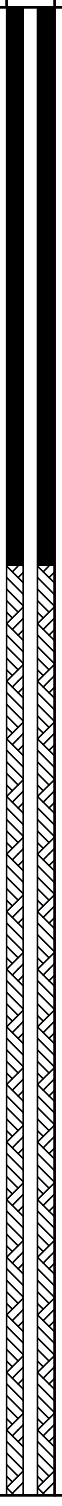
WATER LEVEL DURING DRILLING:
(from ground surface at start of shift)

Date	FL Level	Hole Dpth
04/02	Dry	7.0'
04/05	Dry	82.0'
04/07	Dry	117.0'
04/08	161.3'*	148.0'
04/09	196.4'*	200.0'
04/10	177.4'*	230.4'
04/12	206.5'	290.0'
04/13	206.5'	290.0'
04/14	206.5'	290.0'
04/20	205.6'	290.0'
04/21	205.6'	290.0'
04/23	205.6'	290.0'
04/24	202.0'	314.0'
04/27	197.4'	314.0'

DEPTH | % RECOVERY | SPT | ENGINEERING PROPERTIES: WEATHERING, HARDNESS, FRACTURE DENSITY, RQD | FIELD CLASSIFICATION | LAB CLASSIFICATION | GEOLOGIC UNIT | GRAPHIC | HOLE COMPLETION | CLASSIFICATION AND PHYSICAL CONDITION

220 225 230 235 240 245 250 255 260 265 270 275 280 285 290 295 300 305 310 315 320 325 330 335

Ts



USBR_PN_7 BLACKRKHYDRO.GPJ USBR_PN.GDT 12/13/04 8:40:19 AM

GEOLOGIC LOG OF DRILL HOLE NO. DH-04-2

FEATURE: Black Rock Alternate Damsite
LOCATION: North of Washington State Highway 24
BEGUN: 4/1/04 FINISHED: 6/3/04
DEPTH AND ELEV OF WATER
LEVEL AND DATE MEASURED: 194.1 (1156.46) 6/03/04

PROJECT: Yakima River Basin Water Storage Project
COORDINATES: N 439,391.5 E 1,790,479.2
TOTAL DEPTH: 530.0
DEPTH TO BEDROCK: 144.0

STATE: Washington
GROUND ELEVATION: 1350.6
ANGLE FROM HORIZONTAL: AZIMUTH:
HOLE LOGGED BY: Didricksen/McAffee
REVIEWED BY: R. Link

NOTES	DEPTH	% RECOVERY	SPT	ENGINEERING PROPERTIES: WEATHERING	HARDNESS	FRACTURE DENSITY	RQD	FIELD CLASSIFICATION	LAB CLASSIFICATION	GEOLOGIC UNIT	GRAPHIC	HOLE COMPLETION	CLASSIFICATION AND PHYSICAL CONDITION
04/28 199.7' 314.0' 04/29 200.5' 314.0' 05/05 195.8' 314.0' 05/11 196.0' 314.0' 05/12 196.0' 314.0' 05/13 196.0' 314.0' 05/17 196.0' 314.0' 05/18 194.7' 374.0' 05/19 194.7' 405.0' 05/20 193.3' 405.0' 05/21 193.3' 434.0' 05/22 195.3' 530.0' 06/02 191.8'(?) 526.7' 06/03 194.1' 526.7' * Water level may be influenced from water added by drillers to clean out the hole at the end of shift the previous day. First water was noted at 254.0, producing about 10 GPM. WATER LEVEL AFTER DRILLING: 06/09 197.4' DRILLING TIME: Drilling: 320 hours. hydrotesting: 130 hours Travel/moving: 30 hrs HOLE COMPLETION: The hole was completed with 3-inch PVC and a transducer as follows: 526.7-453.0': Sand pack with slotted (0.020" slot) schedule 40 PVC (3.068" ID) with cap at 526.7-476.7'. 453.0-433.0': Cal-seal cement. 433.0-264.0': Cement. 264.0-46.0': Bentonite chips, with 8-inch casing left from 143.0-103.0'. 46.0-0.0': Cement. Installed standpipe wellhead with about 3.1' stickup. Top of riser at elevation 1353.66'. Aquistar PT2X pressure trasnducer, 30 psi range installed for long-term monitoring.	340 345 350 355 360 365 370 375 380 385 390 395 400 405 410 415 420 425 430 435 440 445 450 455									Teq/Tum			

GEOLOGIC LOG OF DRILL HOLE NO. DH-04-2

FEATURE: Black Rock Alternate Damsite
LOCATION: North of Washington State Highway 24
BEGUN: 4/1/04 FINISHED: 6/3/04
DEPTH AND ELEV OF WATER
LEVEL AND DATE MEASURED: 194.1 (1156.46) 6/03/04

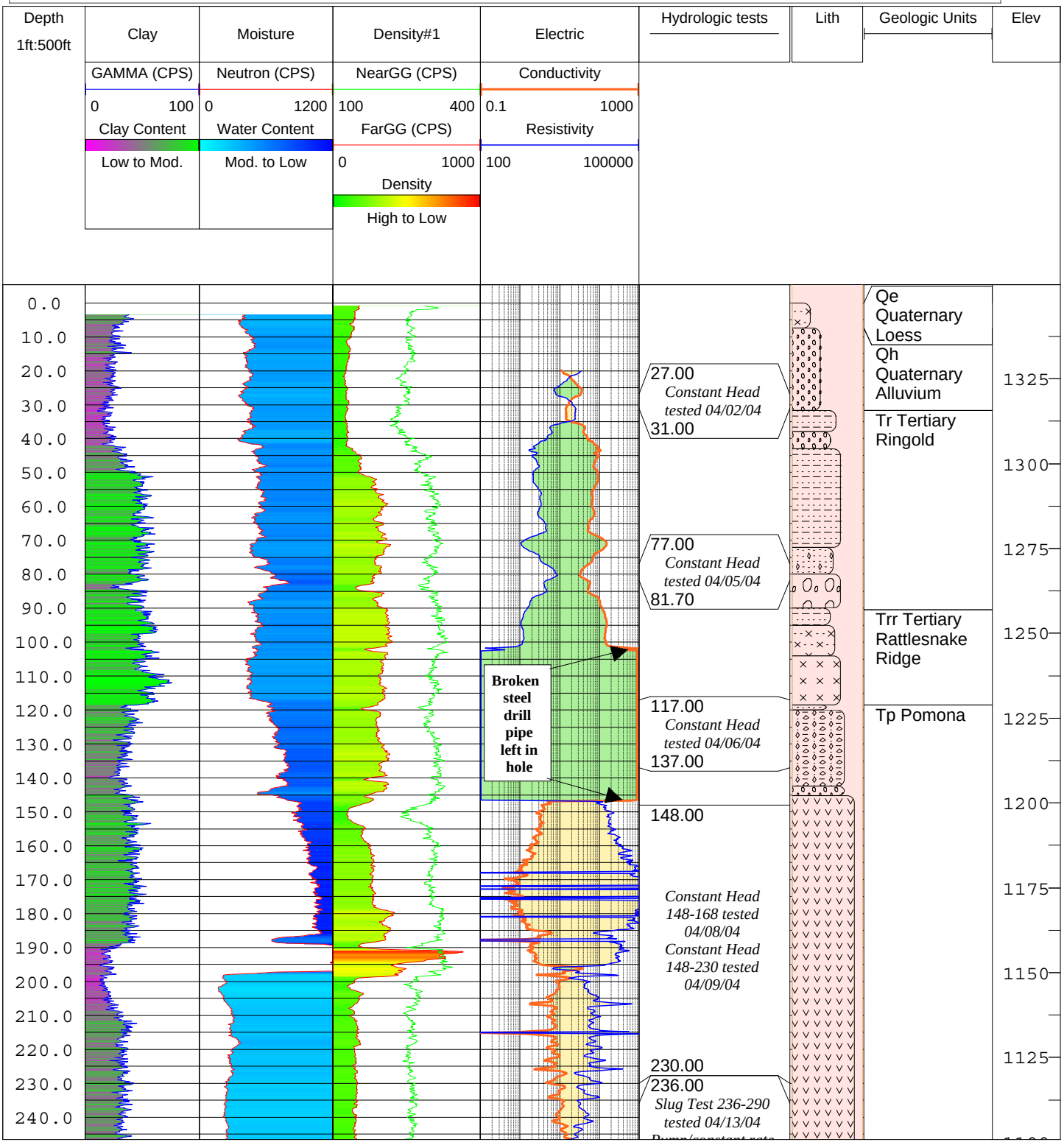
PROJECT: Yakima River Basin Water Storage Project
COORDINATES: N 439,391.5 E 1,790,479.2
TOTAL DEPTH: 530.0
DEPTH TO BEDROCK: 144.0

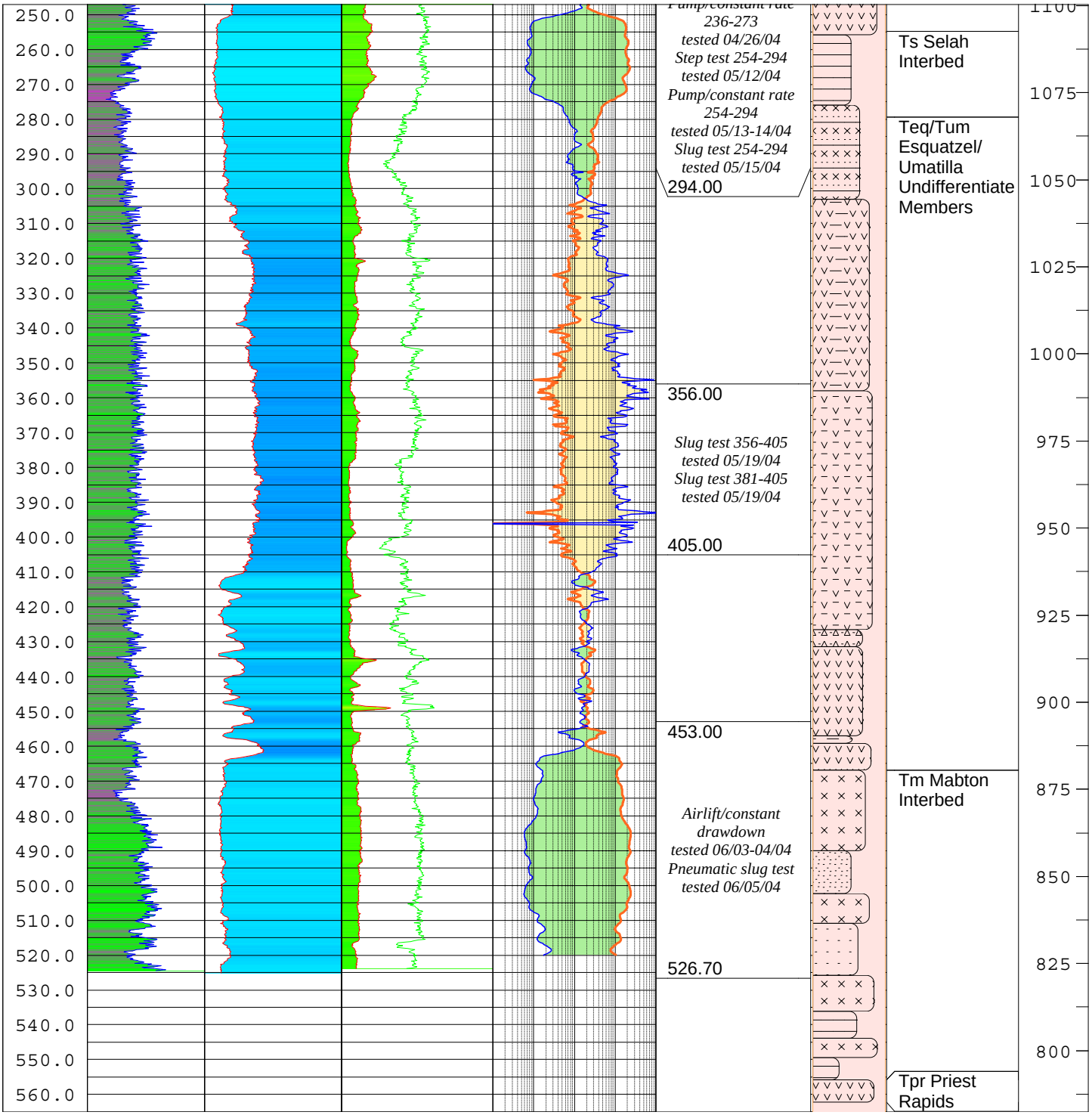
STATE: Washington
GROUND ELEVATION: 1350.6
ANGLE FROM HORIZONTAL: AZIMUTH:
HOLE LOGGED BY: Didricksen/McAffee
REVIEWED BY: R. Link

NOTES	DEPTH	% RECOVERY	SPT	ENGINEERING PROPERTIES: WEATHERING	HARDNESS	FRACTURE DENSITY	RQD	FIELD CLASSIFICATION	LAB CLASSIFICATION	GEOLOGIC UNIT	GRAPHIC	HOLE COMPLETION	CLASSIFICATION AND PHYSICAL CONDITION
	460												
	465												
	470												
	475												
	480												
	485												
	490												
	495									Tm			
	500												
	505												
	510												
	515												
	520												
	525												
	530												
	BOTTOM OF HOLE												

BUREAU OF RECLAMATION

PROJECT Black Rock HOLE NO. DH-04-02




Pump/constant rate
236-273
tested 04/26/04
Step test 254-294
tested 05/12/04
Pump/constant rate
254-294
tested 05/13-14/04
Slug test 254-294
tested 05/15/04
294.00
356.00
Slug test 356-405
tested 05/19/04
Slug test 381-405
tested 05/19/04
405.00
453.00
Airlift/constant
drawdown
tested 06/03-04/04
Pneumatic slug test
tested 06/05/04
526.70
Ts Selah
Interbed
Teq/Tum
Esquatzel/
Umatilla
Undifferentiate
Members
Tm Mabton
Interbed
Tpr Priest
Rapids
250.0
260.0
270.0
280.0
290.0
300.0
310.0
320.0
330.0
340.0
350.0
360.0
370.0
380.0
390.0
400.0
410.0
420.0
430.0
440.0
450.0
460.0
470.0
480.0
490.0
500.0
510.0
520.0
530.0
540.0
550.0
560.0
1100
1075
1050
1025
1000
975
950
925
900
875
850
825
800

Results of Geochemical Analyses

SUMMARY OF SAMPLES FOR GEOCHEMICAL TESTING – BLACK ROCK ALTERNATE DAM SITE, WASHINGTON

Sample No.	Drill Hole Designation	Location (T,R,S)	Depth (ft.)	Sample Type	*Geologic Unit
BRA-1	**DH-04-1**	**T12N, R23E, Sec 11**	**115.0**	**Ash**	**-**
BRA-2	**DH-04-1**	**T12N, R23E, Sec 11**	**221.8 – 222.0**	**Rock Core**	**Pomona**
BRA-3	**DH-04-1**	**T12N, R23E, Sec 11**	**250.2-250.4**	**Rock Core**	**Pomona**
BRA-4	**DH-04-1**	**T12N, R23E, Sec 11**	**283.1-283.3**	**Rock Core**	**Umatilla (Low MgO)**
BRA-5	**DH-04-1**	**T12N, R23E, Sec 11**	**303.2-303.4**	**Rock Core**	**Umatilla**
BRA-6	**DH-04-1**	**T12N, R23E, Sec 11**	**318.9-319.0**	**Rock Core**	**Umatilla**
BRA-7	**DH-04-1**	**T12N, R23E, Sec 11**	**360.5-360.8**	**Rock Core**	**Umatilla**
BRA-8	**DH-04-1**	**T12N, R23E, Sec 11**	**393.3-393.4**	**Rock Core**	**Umatilla**
BRA-9	**DH-04-1**	**T12N, R23E, Sec 11**	**417.5-417.8**	**Rock Core**	**Umatilla**
BRA-10	**DH-04-1**	**T12N, R23E, Sec 11**	**437.0-437.2**	**Rock Core**	**Umatilla**
BRA-11	**DH-04-1**	**T12N, R23E, Sec 11**	**456.0-456.2**	**Rock Core**	**Umatilla (Higher MgO)**
BRA-12	**DH-04-1**	**T12N, R23E, Sec 11**	**560.0-560.3**	**Rock Core**	**Priest Rapids**
BRA-13	**DH-04-1**	**T12N, R23E, Sec 11**	**561.2-561.4**	**Rock Core**	**Tpr**
BRA-14	**DH-03-2**	**T12N, R23E, Sec 14**	**66.0**	**Rock Core**	**Pomona**
BRA-15	**DH-03-3**	**T12N, R23E, Sec 11**	**97.5**	**Rock Core**	**Elephant Mnt (?)**
BRA-16	**DH-03-5**	**T12N, R23E, Sec 14**	**98.0**	**Rock Core**	**Pomona**

*Geologic unit based on sample identification using geochemical data. Identifications were determined by Dr. Robert Bentley (Columbia Geotechnical Associates, Inc.) and informally submitted to Reclamation.

GEOCHEMICAL TEST RESULTS ON SAMPLES FROM DRILL HOLES AT THE BLACK ROCK ALTERNATE DAMSITE

AUGUST 2004

	LIN BRA-2	LIN BRA-3	LIN BRA-4	LIN BRA-5	LIN BRA-6	LIN BRA-7	LIN BRA-8	LIN BRA-9	LIN BRA-10	LIN BRA-11
Date	8-Jul-04	8-Jul-04	8-Jul-04	8-Jul-04	8-Jul-04	8-Jul-04	8-Jul-04	8-Jul-04	9-Jul-04	9-Jul-04
Unnormalized Major Elements (Weight %):										
SiO2	51.93	51.68	54.41	53.70	53.89	53.48	53.36	53.01	52.97	53.17
TiO2	1.655	1.697	2.727	2.737	2.708	2.747	2.807	2.980	2.993	2.986
Al2O3	14.98	14.91	13.82	13.63	13.54	13.43	13.43	13.43	13.49	13.50
FeO*	10.47	10.17	10.33	11.37	11.50	12.11	12.18	12.23	12.51	12.38
MnO	0.175	0.172	0.153	0.186	0.207	0.211	0.211	0.209	0.208	0.213
MgO	6.39	6.78	2.08	2.48	2.63	2.96	3.01	3.20	3.03	3.15
CaO	10.92	10.87	6.55	6.51	6.44	6.39	6.46	6.67	6.75	6.74
Na2O	2.32	2.46	3.00	2.89	3.30	3.11	3.05	2.99	3.14	3.15
K2O	0.73	0.61	3.00	2.96	2.73	2.93	2.94	2.81	2.66	2.65
P2O5	0.229	0.232	0.990	0.963	0.957	0.925	0.898	0.834	0.870	0.856
Total	99.80	99.59	97.07	97.42	97.90	98.29	98.34	98.36	98.64	98.79
Normalized Major Elements (Weight %):										
SiO2	52.04	51.89	56.06	55.12	55.04	54.42	54.26	53.89	53.71	53.82
TiO2	1.658	1.704	2.809	2.810	2.766	2.795	2.854	3.030	3.034	3.022
Al2O3	15.01	14.98	14.24	13.99	13.83	13.66	13.65	13.66	13.67	13.67
FeO*	10.50	10.21	10.65	11.67	11.74	12.32	12.39	12.43	12.69	12.53
MnO	0.175	0.172	0.157	0.191	0.211	0.214	0.214	0.212	0.211	0.216
MgO	6.41	6.81	2.14	2.55	2.69	3.01	3.06	3.25	3.08	3.18
CaO	10.94	10.91	6.74	6.68	6.57	6.50	6.57	6.78	6.85	6.82
Na2O	2.32	2.47	3.09	2.97	3.37	3.16	3.10	3.04	3.18	3.19
K2O	0.73	0.61	3.09	3.04	2.79	2.98	2.99	2.86	2.70	2.68
P2O5	0.230	0.233	1.020	0.988	0.977	0.941	0.913	0.848	0.882	0.866
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Unnormalized Trace Elements (ppm):										
Ni	56	51	2	2	1	2	2	3	2	3
Cr	105	104	3	4	2	4	3	2	1	1
Sc	36	37	27	27	26	27	27	28	27	28
V	280	282	158	166	164	179	190	222	228	224
Ba	473	274	4794	3789	3535	3370	3258	3027	3057	3037
Rb	17	13	54	53	45	49	49	45	46	46
Sr	241	239	324	299	285	276	277	277	283	277
Zr	139	143	534	507	496	480	473	446	453	446
Y	30	31	55	52	50	49	47	47	47	47
Nb	12.2	11.8	23.2	23.1	22.4	22.5	21.2	21.3	21.2	21.5
Ga	19	18	24	22	23	23	20	21	20	20
Cu	49	50	4	3	3	4	4	3	6	5
Zn	98	104	152	139	128	127	129	127	130	127
Pb	6	6	11	12	11	12	10	10	9	10
La	23	17	47	46	48	46	41	45	48	43
Ce	36	41	86	90	86	86	92	78	78	83
Th	2	3	8	7	7	7	5	5	7	6

Major elements are normalized on a volatile-free basis, with total Fe expressed as FeO.
"R" denotes a duplicate bead made from the same rock powder.

Analyses by Washington State University GeoAnalytical Laboratory

GEOCHEMICAL TEST RESULTS ON SAMPLES FROM DRILL HOLES AT THE BLACK ROCK ALTERNATE DAMSITE

AUGUST 2004

	LIN BRA-12	LIN BRA-13	LIN BRA-14	LIN BRA-15	LIN BRA-16	LIN BRA-13	LIN BRA13R
Date	9-Jul-04	9-Jul-04	9-Jul-04	9-Jul-04	9-Jul-04	9-Jul-04	9-Jul-04
Unnormalized Major Elements (Weight %):							
SiO2	50.46	49.02	51.71	50.91	50.96	49.02	48.91
TiO2	3.506	3.476	1.674	3.686	1.637	3.476	3.490
Al2O3	14.75	14.40	14.85	13.07	14.82	14.40	14.37
FeO*	11.43	12.09	10.43	13.82	10.86	12.09	12.30
MnO	0.201	0.542	0.175	0.206	0.162	0.542	0.545
MgO	3.16	3.27	6.66	3.87	6.20	3.27	3.26
CaO	9.91	10.19	10.85	8.77	11.00	10.19	10.14
Na2O	2.92	2.66	2.33	2.45	2.26	2.66	2.66
K2O	1.09	1.01	0.67	1.19	0.41	1.01	1.02
P2O5	0.980	0.818	0.235	0.579	0.233	0.818	0.818
Total	98.42	97.48	99.59	98.55	98.54	97.48	97.51
Normalized Major Elements (Weight %):							
SiO2	51.28	50.29	51.92	51.66	51.72	50.29	50.16
TiO2	3.563	3.566	1.681	3.741	1.661	3.566	3.579
Al2O3	14.99	14.77	14.92	13.27	15.04	14.77	14.73
FeO*	11.62	12.40	10.48	14.02	11.02	12.40	12.61
MnO	0.204	0.556	0.176	0.209	0.164	0.556	0.559
MgO	3.21	3.36	6.69	3.93	6.29	3.36	3.35
CaO	10.07	10.45	10.89	8.90	11.17	10.45	10.40
Na2O	2.97	2.73	2.34	2.49	2.29	2.73	2.73
K2O	1.11	1.04	0.68	1.20	0.42	1.04	1.04
P2O5	0.995	0.839	0.236	0.588	0.237	0.839	0.839
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Ni	37	29	45	12	44	29	30
Cr	103	103	107	15	106	103	103
Sc	41	41	36	32	36	41	41
V	398	403	287	422	284	403	400
Ba	657	525	261	804	247	525	524
Rb	29	30	15	32	10	30	30
Sr	331	324	235	247	250	324	324
Zr	208	208	140	271	142	208	208
Y	64	54	31	52	33	54	55
Nb	16.8	17.1	12.5	26.9	11.9	17.1	16.7
Ga	24	24	20	23	17	24	25
Cu	45	35	48	15	52	35	37
Zn	147	153	96	159	98	153	154
Pb	6	5	5	10	6	5	7
La	33	30	21	38	19	30	24
Ce	75	56	42	80	34	56	69
Th	4	4	2	6	2	4	3

Major elements are normalized on a volatile-free basis, with total Fe expressed as FeO.
"R" denotes a duplicate bead made from the same rock powder.

Analyses by Washington State University GeoAnalytical Laboratory

APPENDIX B

Drawings

Drawing Nos. 33-100-3380 through 33-100-3384
Drawing Nos. 40-D-7022 and 40-D-7023

GENERAL GEOLOGIC LEGEND

Quaternary Units

Qe Quaternary Loess Deposits (Qe). Deposits of Holocene age wind–blown loess blanket the site. The loess consists primarily of brown, dry to moist, non–plastic silt and fine sand.

Qh Quaternary Alluvium Deposits (Qh). The alluvium deposits consist of undifferentiated medium to coarse–grained sand with fines, gravel, cobbles and boulders composed of basaltic detritus from local sources.

Landslide. Landslide debris of unknow age and composition, includes deposits on the northwest and east slopes of Horsethief Mountain, and Horsethief Point.

Tertiary Units

Tr Ringold Formation (Tr). The Ringold is a fluviolaustrine deposit composed of a poorly to well–indurated, subrounded basalt sand, gravel and cobble size clasts in a matrix of fines and silty sand.

Ellensburg Formation.

Tem Elephant Mountain Member (Tem). The Elephant Mountain member consists of medium to fine grained basalt. The member was not encountered in test borings at the alternate dam site, but was logged in drill holes the original dam site, refer to WIS (2003) for detailed description.

Trr Rattlesnake Ridge Member (Trr). The Rattlesnake Ridge member also includes the sedimentary deposits between the Elephant Mountain Basalt and the Pomona Basalt. The unit is composed of fluvial gravel, sand, and cobbles with intensely weathered basalt fragments and tuffaceous silt and clay.

Columbia River Basalt Group – Saddle Mountains Basalt Formation.

Tp Pomona Member (Tp). The Pomona member underlies the valley and the north abutment at the damsite, the basalt has reverse magnetic polarity, is generally black to gray, fine grained, slightly weathered, hard and intensely to moderately fractured, dense basalt with fine plagioclase crystals. The Pomona flow is invasive into the underlying Selah interbed, the upper portion of the flow includes glassy vesicular basalt with inclusions of fine sediment, which is referred to as a peperite.

Ellensburg Formation.

Ts Selah Sedimentary Interbed (Ts). The Selah Interbed is a sedimentary unit composed of tuffaceous siltstone and claystone. The Selah sediments are reddish orange to black, well indurated clay to medium sand –sized lithic fragments composed of pumice, ash and chert.

Columbia River Basalt Group – Saddle Mountains Basalt Formation.

Teq/Tum Esquatzel and Umatilla Members (Teq/Tum). The Esquatzel member is an intercanyon flow that filled ancestral Columbia River channels, sometimes overflowing the channel and pouring out into the floodplain.The Esquatzel member overlies the Umatilla member, and it is difficult to distinguish between the two flows, due to similar characteristics the two members are addressed as a single unit. The flows consist of grey to dark grey, fresh to slightly weathered, hard, moderately to slightly fractured, dense to slightly vesicular, fine–grained basalt. Both basalt have normal magnetic polarity.

Ellensburg Formation.

Tm Mabton Sedimentary Interbed (Tm). The Mabton Interbed is a thick sequence of light green to brown, moderately soft tuffaceous siltstone, sandstone and claystone. The Mabton sediments are light green to dark brown, well indurated, intensely weathered clay silt and sand–size fragments. Traces of black charcoal fragments noted. The interbed represents an extended time period of deposition between eruptions.

Columbia River Basalt Group – Wanapum Basalt Formation

Tpr Priest Rapids Basalt Member (Tpr). The Priest Rapids Member is distinguished by its coarse–grained texture and reverse magnetic polarity. The flows consist of black to dark grey, slightly weathered, hard, intensely to moderately fractured, fine–grained to porphyritic vesicular basalt.

GENERAL GEOLOGIC EXPLANATION

DH–03–5 ● Drill hole location, designation and number.

A A' Location and designation of geologic section.

?..... Geologic contact. Dashed where approximate, queried where inferred, dotted where concealed.

Thrust Fault, dashed where approximate, arrows toward direction of footwall movement.

Anticline, dashed where approximate.

Macho Linear Photographic Linear, dashed where approximate.

Overhead power line.

DH–03–5
EL 1285.5
Proj 81' N)
Drill hole designation.
Elevation of ground surface at collar of drill hole.
Distance and direction of projection (if projected).

T Stick log of drill hole. Dashed when projected more than ten feet to the section.

32.5 Depth to geologic contact.

Tr Geologic unit.

106.5 Total depth of drill hole.

GENERAL GEOLOGIC NOTES

1. The Unified Soil Classification System, Designation USBR 5005–86, "Procedure for Determining Unified Soil Classification (Visual Method)"; Designation USBR 5000–86, Procedure for Determining Unified Soil Classification (Laboratory Method)" were used in describing earth materials sampled in exploratory drill holes.

2. Descriptive terms appearing on geologic logs describe the physical characteristics of materials and conform to standard definitions as given in "Engineering Geology Field Manual, Volume I, 2nd Edition" (USBR, 1998) and "Volume II, 2nd Edition" (USBR, 2001).

3. General Geologic Explanation, Legend and Notes to accompany dwgs: 33–100–3381 through –3384.

ALWAYS THINK **SAFETY**

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA RIVER BASIN WATER STORAGE FEASIBILITY STUDY – WASHINGTON

BLACK ROCK DAMSITE

GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES

GEOLOGY D.STELMA CHECKED DS
DRAWN T.ENGLAND TECH. APPR. DOUGLAS J. BENNETT
APPROVED RICHARD A. LINK
PEER REVIEWER – REGIONAL GEOLOGIST

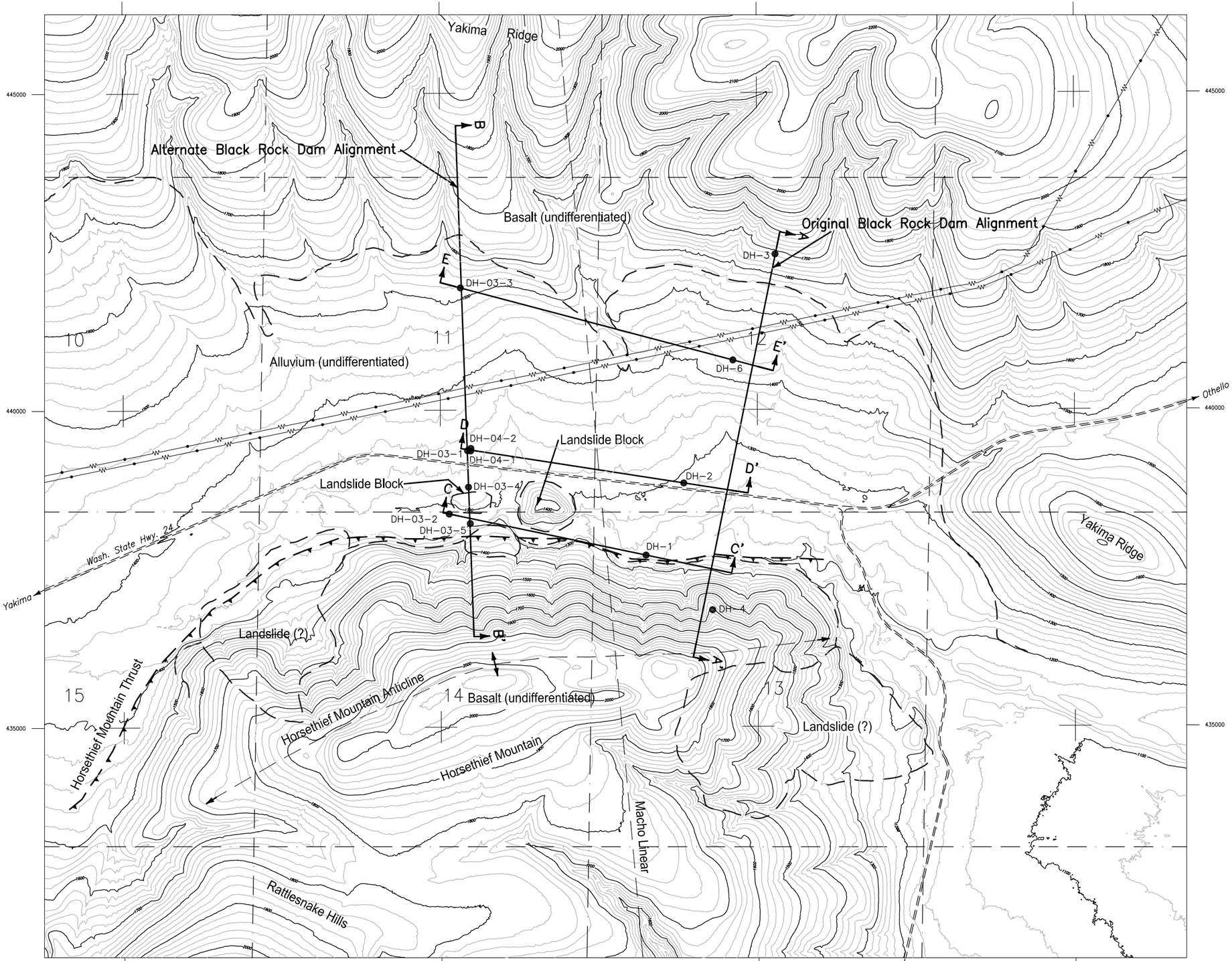
CAD SYSTEM ACAD 2004 | geo\blackrock\dwgs\33–100–3380
BOISE, IDAHO SHEET 1 OF 1 2004, JUNE 15 | 33–100–3380

Notes:

1 General surface geology and tectonic features from report titled "Black Rock Reservoir, Initial Geotechnical Investigation, Prepared for Benton County Sustainable Development by Washington Infrastructures Services, Inc., Dated January 2003."

2 Locations and stick-log information for drill holes DH-1, DH-2, DH-3, DH-4 and DH-6 from from report titled "Black Rock Reservoir, Initial Geotechnical Investigation, Prepared for Benton County Sustainable Development by Washington Infrastructures Services, Inc., Dated January 2003."

3. For Geologic Sections refer to Drawing 33-100-3382, -3383 and -3384. For Geologic Explantion, Legend and Notes refer to Drawing 33-100-3380.



800 0 800 1600 2400

SCALE OF FEET

CONTOUR INTERVAL = 20 FEET

ALWAYS THINK **SAFETY**

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA RIVER BASIN WATER STORAGE FEASIBILITY STUDY - WASHINGTON

BLACK ROCK DAM SITE

GEOLOGIC PLAN MAP, LOCATIONS OF EXPLORATIONS AND SECTIONS

GEOLOGY_ D.STELMA _ _ _ _ _ _ _ _ CHECKED _ _ DS _ _ _ _ _ _ _ _ _ _ _ _ _

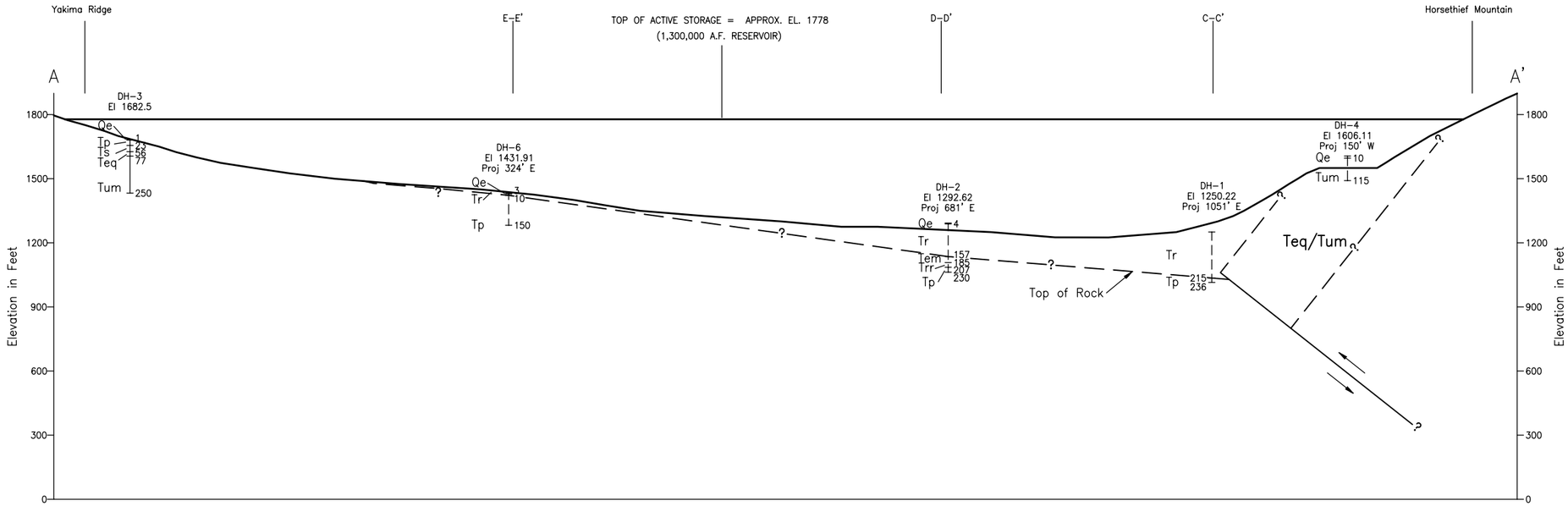
DRAWN_ _ T.ENGLAND _ _ _ _ _ _ _ _ TECH. APPR._ DOUGLAS J. BENNETT _ _ _ _ _

APPROVED _ _ RICHARD A. LINK _ _ _ _ _ _ _ _ _ _ _
PEER REVIEWER - REGIONAL GEOLOGIST

CAD SYSTEM ACAD 2004 | geo\blackrock\dwgs\33-100-3381

BOISE, IDAHO SHEET 1 OF 1 2004, JUNE 15

33-100-3381



Original (East) Alignment

Geologic Units

Alluvial Units	Qe	Pediment Deposits
	Qh	Alluvium Deposits
	Tr	Ringold Formation
Bedrock Units	Tem	Elephant Mountain Member
	Trr	Rattlesnake Ridge Member
	Tp	Pomona Member
	Ts	Selah Interbed
	Teq	Esquatzel Member
	Tum	Umatilla Member
	Tm	Mabton Interbed
	Tpr	Priest Rapids Member

Notes:

1 General geology and tectonic features from report titled "Black Rock Reservoir, Initial Geotechnical Investigation, Prepared for Benton County Sustainable Development by Washington Infrastructures Services, Inc., Dated January 2003."

2 Locations and stick-log information for drill holes DH-1, DH-2, DH-3, DH-4 and DH-6 from f rom report titled "Black Rock Reservoir, Initial Geotechnical Investigation, Prepared for Benton County Sustainable Development by Washington Infrastructures Services, Inc., Dated January 2003."

3. For Location of Geologic Section refer to Drawing 33-100-3381. For Geologic Explantion, Legend and Notes refer to Drawing 33-100-3380.

300 0 300 600 900
SCALE OF FEET

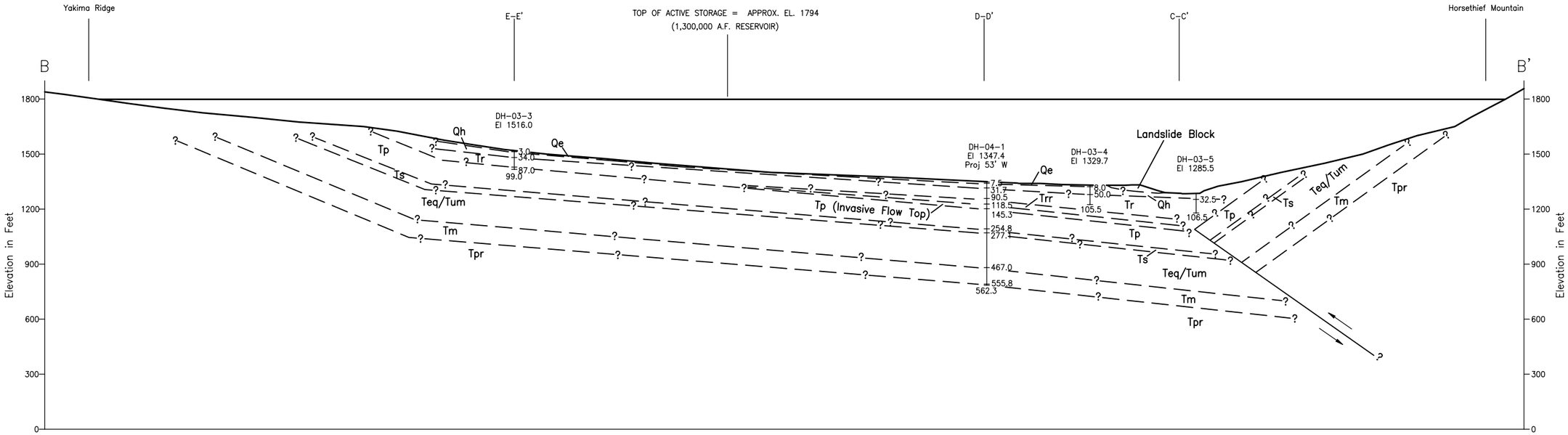
ALWAYS THINK **SAFETY**

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA RIVER BASIN WATER STORAGE FEASIBILITY STUDY - WASHINGTON

BLACK ROCK DAM SITE
(ORIGINAL ALIGNMENT)
GEOLOGIC SECTION A-A'

GEOLOGY_ STELMA / MCAFFEE _ _ _ _ _ CHECKED _ _ DS _ _ _ _ _ _ _ _ _ _ _ _
DRAWN_ _ T.ENGLAND_ _ _ _ _ _ _ _ TECH. APPR._ DOUGLAS J. BENNETT_ _ _ _ _ _
APPROVED _ _ RICHARD A. LINK_ _ _ _ _ _ _ _ _ _ _
PEER REVIEWER - REGIONAL GEOLOGIST

CAD SYSTEM ACAD 2004 | geo\blackrock\dwgs\33-100-3382
BOISE, IDAHO SHEET 1 OF 1 2004, JUNE 15 | 33-100-3382



Alternate (West) Alignment

Geologic Units

Alluvial Units	Qe	Pediment Deposits
	Qh	Alluvium Deposits
	Tr	Ringold Formation
Bedrock Units	Trr	Rattlesnake Ridge Member
	Tp	Pomona Member
	Ts	Selah Interbed
	Teq	Esquatzel Member
	Tum	Umatilla Member
	Tm	Mabton Interbed
	Tpr	Priest Rapids Member

Notes:

1. General geology and tectonic features from report titled "Black Rock Reservoir, Initial Geotechnical Investigation, Prepared for Benton County Sustainable Development by Washington Infrastructures Services, Inc., Dated January 2003."

2. For Location of Geologic Section refer to Drawing 33–100–3381. For Geologic Explantion, Legend and Notes refer to Drawing 33–100–3380.

300 0 300 600 900
SCALE OF FEET

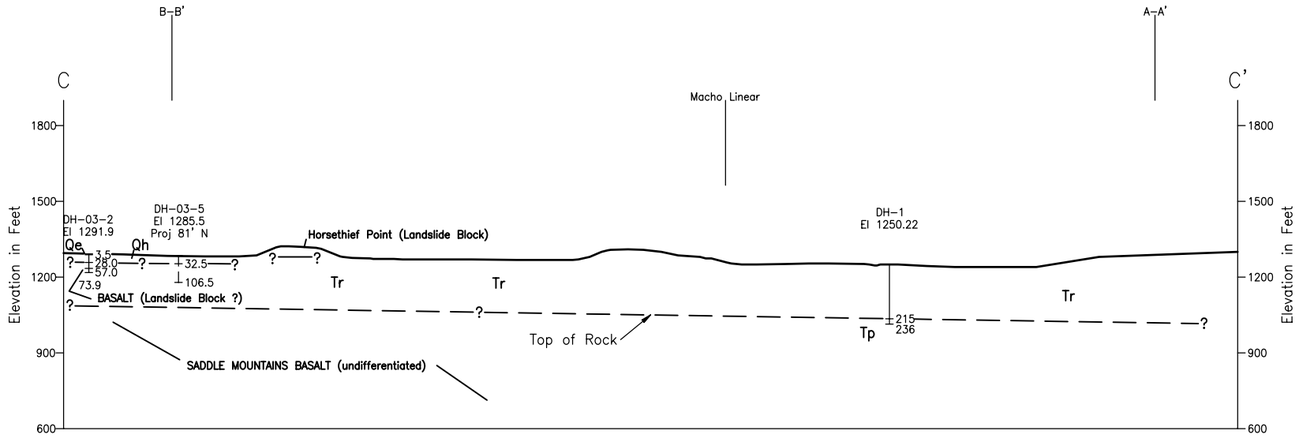
ALWAYS THINK **SAFETY**

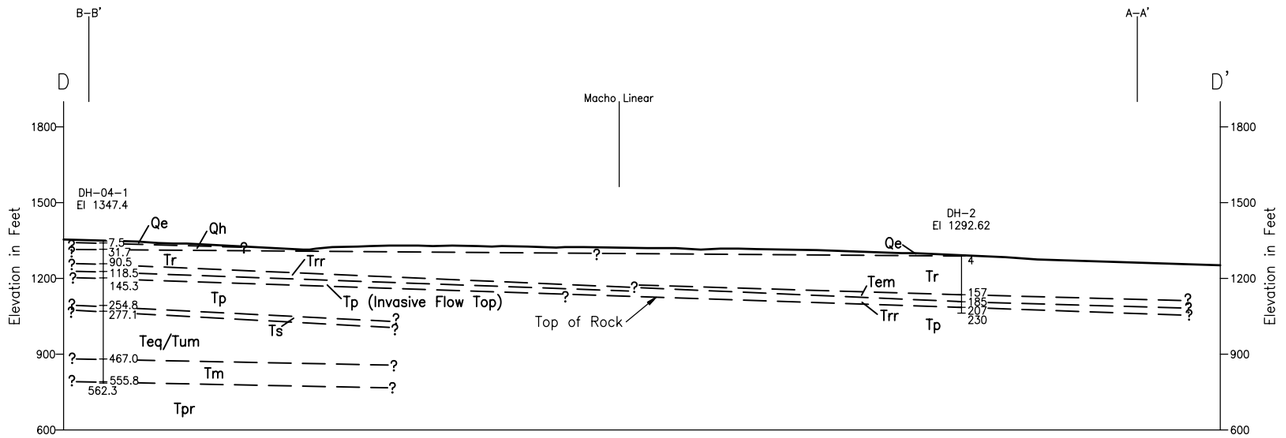
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA RIVER BASIN WATER STORAGE FEASIBILITY STUDY – WASHINGTON

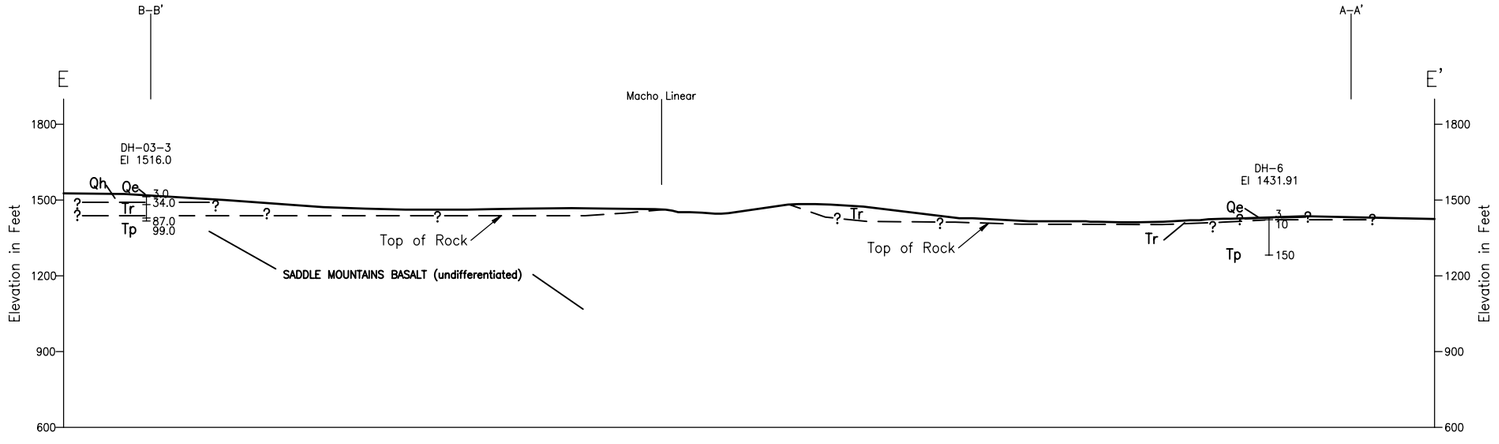
BLACK ROCK DAM SITE
(ALTERNATE ALIGNMENT)
GEOLOGIC SECTION B–B'

GEOLOGY_ STELMA / MCAFFEE _ _ _ _ _ CHECKED _ _DS _ _ _ _ _ _ _ _ _ _ _ _ _
DRAWN_ _T.ENGLAND_ _ _ _ _ _ _ _ _ TECH. APPR._ DOUGLAS J. BENNETT _ _ _ _ _ _
APPROVED _ _RICHARD A. LINK_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _
PEER REVIEWER – REGIONAL GEOLOGIST

CAD SYSTEM ACAD 2004 | geo\blackrock\dwgs\33–100–3383
BOISE, IDAHO SHEET 1 OF 1 2004, JUNE 15 | 33–100–3383







Notes:

1 General geology and tectonic features from report titled "Black Rock Reservoir, Initial Geotechnical Investigation, Prepared for Benton County Sustainable Development by Washington Infrastructures Services, Inc., Dated January 2003."

2 Locations and stick-log information for drill holes DH-1, DH-2, and DH-6 from from report titled "Black Rock Reservoir, Initial Geotechnical Investigation, Prepared for Benton County Sustainable Development by Washington Infrastructures Services, Inc., Dated January 2003."

3. For Location of Geologic Sections refer to Drawing 33-100-3381. For Geologic Explantion, Legend and Notes refer to Drawing 33-100-3380.

Geologic Units

Alluvial Units	Qe	Pediment Deposits
	Qh	Alluvium Deposits
	Tr	Ringold Formation
Bedrock Units	Tem	Elephant Mountain Member
	Trr	Rattlesnake Ridge Member
	Tp	Pomona Member
	Ts	Selah Interbed
	Teq	Esquatzel Member
	Tum	Umatilla Member
	Tm	Mabton Interbed
	Tpr	Priest Rapids Member

300 0 300 600 900
SCALE OF FEET

ALWAYS THINK **SAFETY**

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA RIVER BASIN WATER STORAGE FEASIBILITY STUDY – WASHINGTON

BLACK ROCK DAM SITE

GEOLOGIC SECTIONS C–C', D–D' AND E–E'

GEOLOGY_ STELMA / MCAFFEE _ _ _ _ _ CHECKED _ _DS _ _ _ _ _ _ _ _ _ _ _ _
DRAWN_ _T.ENGLAND_ _ _ _ _ _ _ _ _ TECH. APPR._ DOUGLAS J. BENNETT _ _ _ _ _ _
APPROVED _ _RICHARD A. LINK_ _ _ _ _ _ _ _ _ _ _
PEER REVIEWER – REGIONAL GEOLOGIST

CAD SYSTEM ACAD 2004 | geo\blackrock\dwgs\33-100-3384
BOISE, IDAHO SHEET 1 OF 1 2004, JUNE 15 | 33-100-3384

WEATHERING

FRESH (W1): Body of rock is not oxidized or discolored; fracture surfaces are not oxidized or discolored*; no separation of grain boundaries; no change of texture and no solutioning. Hammer rings when crystalline rocks are struck.

SLIGHTLY WEATHERED TO FRESH (W2):**

SLIGHTLY WEATHERED (W3): Discoloration or oxidation is limited to surface of, or short distance from fractures; some feldspar crystals are dull; fracture surfaces have minor to complete discoloration or oxidation; no visible separation of grain boundaries; texture preserved and minor leaching of soluble minerals may be present. Hammer rings when crystalline rocks are struck, body of rock is not weakened by weathering.

MODERATELY TO SLIGHTLY WEATHERED (W4):**

MODERATELY WEATHERED (W5): Discoloration or oxidation extends from fractures, usually throughout body of rock; ferromagnesian minerals are "rusty", feldspar crystals are "cloudy"; all fracture surfaces are discolored or oxidized; partial opening of grain boundaries visible; texture generally preserved, but soluble minerals may be mostly leached. Hammer does not ring when rock is struck, body of rock is slightly weakened.

INTENSELY TO MODERATELY WEATHERED (W6):**

INTENSELY WEATHERED (W7): Body of rock is discolored or oxidized throughout; all feldspars and ferromagnesian minerals are altered to clay to some extent. All fracture surfaces are discolored or oxidized, and friable; partial separation of grain boundaries, rock is friable; in situ disaggregation of granitics common in semi-arid regions; texture altered and leaching of soluble minerals may be complete. Rock has dull sound when struck with hammer; rock is weakened, usually can be broken with moderate to heavy manual pressure or by light hammer blow without reference to planes of weakness.

VERY INTENSELY WEATHERED (W8):**

DECOMPOSED (W9): Body of rock is discolored or oxidized throughout, but resistant minerals such as quartz may be unaltered; all feldspars and ferro-magnesian minerals are completely altered to clay; complete separation of grain boundaries (disaggregated), partial or complete remnant rock structure may be preserved, but resembles a soil.

NOTE: Weathering categories are established primarily for crystalline rocks and those with ferromagnesian minerals, weathering in various sedimentary rocks will not always fit the categories established – weathering categories may be modified for particular site conditions or alteration such as hydrothermal alteration. Where modified criteria are established, they should be identified and described.

* Characteristics of fracture surfaces do not include directional weathering along shears or faults and their associated fracture zones; for example a shear that carries weathering to great depths in a fresh rock mass would not require the whole rock mass to be classified as weathered.

** Combination descriptors are used when equal distribution of both weathering characteristics are present over significant intervals or where characteristics noted are "in between" the diagnostic characteristics.

DURABILITY INDEX

DURABILITY DESCRIPTOR	DESCRIPTIVE CRITERIA
DIØ	Rock specimen or exposure remains intact with no deleterious cracking after exposure longer than 1 year.
DI1	Rock specimen or exposure develops hairline cracking on surfaces within 1 month, but no disaggregation within 1 year of exposure.
DI2	Rock specimen or exposure develops hairline cracking on surfaces within 1 week, and/or disaggregation within 1 month of exposure.
DI3	Specimen or exposure may develop hairline cracks in 1 day and displays pronounced separation of bedding and/or disaggregation within 1 week of exposure.
DI4	Specimen or exposure displays pronounced cracking and disaggregation within 1 day (24 hours) of exposure. Generally ravels and degrades to small fragments.

COLOR

The Munsell color system (Geologic Society of America Rock Color Chart) should be used. This system defines wet color by its hue, value, and chroma. Color symbols used (i.e., 5 YR 5/6 may be included).

SEDIMENTARY AND PYROCLASTIC ROCK PARTICLE SIZES

Size in mm	Sedimentary Rounded, subrounded, subangular		Pyroclastic	
	Particle or fragment	Lithified product	Fragment	Lithified product
256	Boulder	Boulder conglomerate	Block[a] or Bomb[b]	Volcanic[a] breccia or Volcanic[b] agglomerate
64	Cobble	Cobble conglomerate		
4	Pebble	Pebble conglomerate	Lapilli	Lapillistone and Lapilli tuff
2	Granule	Granule conglomerate		
1	Very coarse sand	Sandstone (Very coarse, coarse, medium, fine, or very fine)	Coarse ash	Coarse tuff
0.5	Coarse sand			
0.25	Medium sand			
0.125	Fine sand			
0.0625	Very fine sand			
0.00391	Silt	Siltstone/ Shale	Fine ash	Fine tuff
	Clay	Claystone Shale		

(a) Broken from previous igneous rock, block shaped (angular to subangular).
(b) Solidified from plastic material while in flight, rounded clasts.

IGNEOUS AND METAMORPHIC ROCK TEXTURE

TEXTURE DESCRIPTOR	AVERAGE GRAIN DIAMETER
VERY COARSE GRAINED OR PEGMATITIC	>10 mm [>3/8 in]
COARSE GRAINED	5-10 mm [3/16 -3/8 in]
MEDIUM GRAINED	1-5 mm [1/32 -3/16 in]
FINE GRAINED	0.1-1 mm [0.004 - 1/32 in]
APHANITIC (Cannot be seen with the unaided eye)	<0.1 mm [<0.004 in]

ADDITIONAL TEXTURAL ADJECTIVES

PIT (pitted) – pinhole to 0.03 ft [3/8 in] (<1 to 10 mm) openings.

VUG (vuggy) – Small openings (usually lined with crystals) ranging in diameter from 0.03 ft [3/8 in] to 0.33 ft [4 in] (10 to 100 mm).

CAVITY – An opening larger than 0.33 ft [4 in] (100 mm), size descriptions are required, and adjectives such as small, large, etc., may be used.

HONEYCOMBED – If numerous enough that only thin walls separate individual pits or vugs, this term further describes the preceding nomenclature to indicate cell-like form.

VESICLE (vesicular) – Small openings in volcanic rocks of variable shape and size formed by entrapped gas bubbles during solidification.

BEDDING FOLIATION OR FLOW TEXTURE

DESCRIPTORS	THICKNESS/SPACING
MASSIVE	Greater than 10 ft (>3 m)
VERY THICKLY (bedded, foliated or banded)	3 to 10 ft (1 to 3 m)
THICKLY	1 to 3 ft (300 mm to 1 m)
MODERATELY	0.3 to 1 ft (100 to 300 mm)
THINLY	0.1 to 0.3 ft (30 to 100 mm)
VERY THINLY	0.03 [3/8 in] to 0.1 ft (10 to 30 mm)
LAMINATED (Intensely foliated or banded)	Less than 0.03 ft [3/8 in] (<10 mm)

BEDROCK HARDNESS/STRENGTH

EXTREMELY HARD (H1): Core, fragment or exposure cannot be scratched with knife or sharp pick; can only be chipped with repeated heavy hammer blows.

VERY HARD (H2): Cannot be scratched with knife or sharp pick. Core or fragment breaks with repeated heavy hammer blows.

HARD (H3): Can be scratched with knife or sharp pick with difficulty (heavy pressure). Heavy hammer blow required to break specimen.

MODERATELY HARD (H4): Can be scratched with knife or sharp pick with light or moderate pressure. Core or fragment breaks with moderate hammer blow.

MODERATELY SOFT (H5): Can be grooved 1/16 inch (2 mm) deep by knife or sharp pick with moderate or heavy pressure. Core or fragment breaks with light hammer blow or heavy manual pressure.

SOFT (H6): Can be grooved or gouged easily by knife or sharp pick with light pressure, can be scratched with fingernail. Breaks with light to moderate manual pressure.

VERY SOFT (H7): Can be readily indented, grooved or gouged with fingernail, or carved with a knife. Breaks with light manual pressure.

Any bedrock unit softer than H7, Very Soft, is to be described using USBR 5005-86 (visual classification of soils) consistency characteristics.

REV NO.		
1	3-8-00 D - P. M. R.	CONVERTED ORIGINAL DRAWING 40-D-6493 TO ACAD, CHANGED DWG. NO., MINOR REVISIONS.

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

GEOLOGY FOR DESIGN & SPECIFICATIONS

STANDARD DESCRIPTORS AND DESCRIPTIVE CRITERIA FOR ROCK

GEOLOGY NOMENCLATURE COMMITTEE CHECKED CHUCK SULLIVAN
DRAWN MARSHALL MONSON TECH. APPROVAL PETER M. ROHRER
APPROVED MARK McKEOWN (PEER REVIEWER)

CADD SYSTEM	CADD FILENAME	DATE AND TIME PLOTTED
AutoCAD Rel. 16.0 DENVER, COLORADO	40-D-7022.DWG MARCH 8, 2000	JANUARY 27, 2005 10:21

40-D-7022

DISCONTINUITY TERMINOLOGY

DISCONTINUITY – A collective term used for all structural breaks in geologic materials which usually are unhealed and have zero or low tensile strength. Discontinuities also may be healed and exhibit high tensile strength. Discontinuities comprise fractures (including joints), planes of weakness, shears/faults, and shear/fault zones. Contacts between various units also may be considered discontinuities.

FRACTURE – A term used to describe any natural break in geologic material excluding shears and shear zones. Additional fracture terminology is provided below.

SHEAR – A structural break where differential movement has taken place along a surface or zone of failure by shear; characterized by striations, slickensides, gouge, breccia, mylonite, or any combination of these. Often direction, amount of displacement, and continuity may not be known because of limited exposures or observations.

FAULT – A shear with significant continuity which can be correlated between observations; occurs over a significant portion of a given site, foundation area, or region; or is a segment of a fault or fault zone defined in the literature. The designation of a shear as a fault or fault zone is a site–specific determination.

SHEAR/FAULT ZONE – A shear that is expressed in relative terms of width. The zone may consist of gouge, breccia, or many related faults or shears together with fractured and crushed rock between the shears and faults, or any combination of these. In the literature many fault zones simply are referred to as faults.

SHEAR–/FAULT–DISTURBED ZONE – An associated zone of fractures and/or folds adjacent to a shear or shear zone where the country rock has been subjected to only minor cataclastic action and may be mineralized. If adjacent to a fault or fault zone, the term is fault–disturbed zone. Occurrence, orientation, and areal extent of these phenomena depend upon depth of burial (pressure and temperature) during shearing, brittleness of materials, and the stress envelope.

FRACTURE TERMINOLOGY

EXAMPLES SHOWN FOR CORE, BUT APPLICABLE TO ANY OBSERVATION

JOINT (JT) – A relatively planar fracture along which there has been little or no shearing displacement.

FOLIATION JOINT (FJ) OR BEDDING JOINT (BJ) – a relatively planar fracture which is parallel to foliation or bedding along which there has been little or no shearing displacement.

BEDDING PLANE SEPARATION – A separation along bedding after extraction or exposure due to stress relief or slaking.

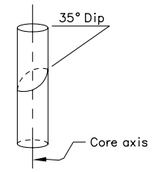
INCIPIENT JOINT (IJ) OR INCIPIENT FRACTURE (IF) – A joint or fracture which does not continue through the specimen or at least is not seen with the naked eye. However, when the specimen is wetted, and then allowed to dry, the joint or fracture trace is evident. When core is broken, it breaks along an existing plane.

RANDOM FRACTURE (RF) – A natural break which does not belong to a joint set, and which exhibits a generally rough, very irregular, nonplanar surface.

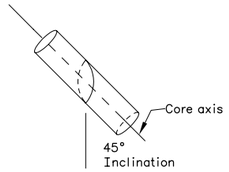
MECHANICAL BREAK (MB) – A break due to drilling, blasting, or handling. Mechanical breaks parallel to bedding or foliation are called Bedding Breaks (BB) or Foliation Breaks (FB), respectively. Recognizing mechanical breaks may be difficult. The absence of oxidation, staining, or mineral fillings, and often a hackly or irregular surface are clues for recognition.

FRACTURE ZONE (FZ) – Numerous, very closely spaced intersecting fractures. Often fragmented core cannot be fitted together.

METHOD OF MEASURING DIP OF PLANAR DISCONTINUITIES, FOLIATION, AND BEDDING IN CORE



1. Vertical hole – true dip is measured and reported.



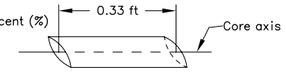
2. Angle hole – true dip usually not known; angle is measured from core axis and is called inclination.

ROCK QUALITY DESIGNATION (RQD)

EXAMPLE SHOWN FOR CORE, BUT APPLICABLE TO ANY LINEAR OBSERVATION

$$RQD = \frac{\text{Sum of length of solid core pieces} > 0.33 \text{ ft [4 in] (100 mm) long}}{\text{Length of the run in feet (mm)}} \times 100$$

Expressed as percent (%)



FRACTURE FREQUENCY

FRACTURE FREQUENCY – The number of natural fractures occurring within a base length or core run. The number of fractures is divided by the length and is reported as fractures per foot or fractures per meter. Expressed as 3/m or 6/ft.

FRACTURE DENSITY

FRACTURE DENSITY – Based on the spacing of all natural fractures in an exposure or core recovery lengths in boreholes; excludes mechanical breaks, shears, and shear zones; however, shear–disturbed zones (fracturing outside the shear) are included. Descriptors for fracture density apply to all rock exposures such as tunnel walls, dozer trenches, outcrops, or foundation cut slopes and inverts, as well as boreholes. Descriptive criteria presented below are based on borehole cores where lengths are measured along the core axis. For other exposures the criterium is distance measured between fractures (size of blocks).

UNFRACTURED (FD0): No fractures.

VERY SLIGHTLY FRACTURED (FD1): Core recovered mostly in lengths greater than 3 feet (1 m).

SLIGHTLY TO VERY SLIGHTLY FRACTURED (FD2) *

SLIGHTLY FRACTURED (FD3): Core recovered mostly in lengths from 1 to 3 feet (300 to 1000 mm) with few scattered lengths less than 1 foot (300 mm) or greater than 3 feet (1000 mm).

MODERATELY TO SLIGHTLY FRACTURED (FD4) *

MODERATELY FRACTURED (FD5): Core recovered mostly in 0.3– to 1.0–foot (100– to 300–mm) lengths with most lengths about 0.6 foot (200 mm).

INTENSELY TO MODERATELY FRACTURED (FD6) *

INTENSELY FRACTURED (FD7): Lengths average from 0.1 to 0.3 foot (30 to 100 mm) with scattered fragmented intervals. Core recovered mostly in lengths less than 0.3 foot (100 mm).

VERY INTENSELY TO INTENSELY FRACTURED (FD8) *

VERY INTENSELY FRACTURED (FD9): Core recovered mostly as chips and fragments with a few scattered short core lengths.

* Combinations of fracture densities (e.g., Very Intensely to Intensely Fractured or Moderately to Slightly Fractured) are used where equal distribution of both fracture density characteristics are present over a significant interval or exposure, or where characteristics are "in between" the descriptor definitions.

FRACTURE SPACING

JOINT SET, OR FRACTURE SPACING DESCRIPTOR	TRUE SPACING
EXTREMELY WIDELY SPACED (SP1)	Greater then 10 ft (>3 m)
VERY WIDELY SPACED (SP2)	3 to 10 ft (1 to 3 m)
WIDELY SPACED (SP3)	1 to 3 ft (300 mm to 1 m)
MODERATELY SPACED (SP4)	0.3 to 1 m (100 to 300 mm)
CLOSELY SPACED (SP5)	0.1 to 0.3 ft (30 to 100 mm)
VERY CLOSELY SPACED (SP6)	less than 0.1 ft (<30 mm)

FRACTURE CONTINUITY

CONTINUITY DESCRIPTOR	DISCONTINUITY LENGTH
DISCONTINUOUS (C1)	Less than 3 ft (<1 m)
SLIGHTLY CONTINUOUS (C2)	3 to 10 ft (1 to 3 m)
MODERATELY CONTINUOUS (C3)	10 to 30 ft (3 to 10 m)
HIGHLY CONTINUOUS (C4)	30 to 100 ft (10 to 30 m)
VERY CONTINUOUS (C5)	Greater than 100 ft (>30 m)

FRACTURE ENDS (JOINT SURVEYS)

FRACTURE ENDS DESCRIPTOR	DESCRIPTIVE CRITERIA
EØ	Zero ends leave the exposure (both ends can be seen).
E1	One end of the fracture terminates in the exposure (one end can be seen).
E2	Neither fracture end terminates in the exposure (neither end can be seen).

FRACTURE OPENNESS OR FILLING THICKNESS

FILLING THICKNESS DESCRIPTOR	THICKNESS/OPENNESS	OPENNESS DESCRIPTOR
CLEAN (TØ)	No film or coating.	
	No visible separation.	TIGHT (OØ)
VERY THIN (T1)	Less than 0.003 ft [1/32 in] (<1 mm).	SLIGHTLY OPEN (O1)
MODERATELY THIN (T2)	0.003 to 0.01 ft [1/32 to 1/8 in] (1 to 3 mm).	MODERATELY OPEN (O2)
THIN (T3)	0.01 to 0.03 ft [1/8 to 3/8 in] (3 to 10 mm).	OPEN (O3)
MODERATELY THICK (T4)	0.03 ft [3/8 in] to 0.1 ft (10 to 30 mm).	MODERATELY WIDE (O4)
THICK (T5)	Greater than 0.1 ft (>30 mm). Actual thickness or openings recorded.	WIDE (O5)

FRACTURE MOISTURE CONDITIONS

MOISTURE DESCRIPTOR	DESCRIPTIVE CRITERIA
M1	The fracture is dry. It is tight or filling (where present) is of sufficient density or composition to impede waterflow. Waterflow along the fracture does not appear possible.
M2	The fracture is dry with no evidence of previous waterflow. Waterflow appears possible.
M3	The fracture is dry, but shows evidence of waterflow such as staining, leaching and/or vegetation.
M4	The fracture or filling (where present) is damp, but no free water is present.
M5	The fracture shows seepage. It is wet with occasional drops of water.
M6	The fracture emits a continuous flow (estimate flow rate) under low pressure. Filling materials (where present) may show signs of leaching or piping.
M7	The fracture emits a continuous flow (estimate flow rate) under moderate to high pressure. Water is squirting and/or filling material (where present) may be substantially washed out.

FRACTURE ROUGHNESS

Refers to small–scale asperities of surfaces, not large–scale undulations or waviness.

STEPPED (R1): Near–normal steps and ridges occur on the fracture surface.
ROUGH (R2): Large, angular asperities can be seen.
MODERATELY ROUGH (R3): Asperities are clearly visible and fracture surface feels abrasive.
SLIGHTLY ROUGH (R4): Small asperities on the fracture surface are visible and can be felt.
SMOOTH (R5): No asperities, smooth to the touch.
POLISHED (R6): Extremely smooth and shiny.

FRACTURE SURFACE AND/OR FILLING ALTERATION AND HARDNESS

Descriptors for weathering or alteration of fracture surfaces and fracture fillings (excluding soil materials) are the same as those used for weathering and alteration of rock.

Descriptors for hardness/strength of fillings and/or fracture surfaces are the same as those presented for hardness of rock and consistency of soils.

DISCONTINUITY HEALING

TOTALLY HEALED (HL1) – All fragments bonded, discontinuity is completely healed or recemented to a degree at least as hard as surrounding rock.

MODERATELY HEALED (HL3) – Greater than 50 percent of fractured or sheared material, discontinuity surfaces or filling is healed or recemented; and/or strength of healing agent is less hard than surrounding rock.

PARTLY HEALED (HL5) – Less than 50 percent of fractured or sheared material, discontinuity surface or filling is healed or recemented.

NOT HEALED (HL6) – Discontinuity surface, fractured zone, sheared material or filling is not healed or recemented, rock fragments or filling (if present) held in place by their own angularity and/or cohesiveness.

SHEAR/FAULT DESCRIPTORS

SHEAR/FAULT GOUGE CONSISTENCY

DESCRIPTOR	DESCRIPTIVE CRITERIA (Similar to consistency of soils)
VERY HARD	Gouge cannot be broken with finger pressure; cannot be indented with fingernail.
HARD	Gouge can be broken with firm finger pressure; can be indented with fingernail; cannot be indented with thumb.
FIRM	Gouge can be easily crumbled; can be indented with thumb 1 to 5 mm.
SOFT	Gouge can be easily molded; can be penetrated with thumb 5 to 25 mm.
VERY SOFT	Gouge can be penetrated with thumb more than 25 mm.

SHEAR/FAULT MOISTURE DESCRIPTORS

The apparent moisture content of gouge is described as WET (visible free water); MOIST (damp, but no visible water); and DRY (absence of moisture, dusty, dry to the touch). Moisture descriptors M1 through M7 may be used to describe the shear or shear zone.

BRECCIA SHAPES

Angular . . . . . 

Subangular . . . . . 

Subrounded . . . . . 

Rounded . . . . . 

Platy . . . . . 

Lens–shaped . . . . . 

Wedge–shaped . . . . . 

Contorted . . . . . 

REV NO		
1	3–8–00 D – P. M. R.	CONVERTED ORIGINAL DRAWING 40–D–6499 TO ACAD, CHANGED DWG. NO., MINOR REVISIONS.

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

GEOLOGY FOR DESIGN & SPECIFICATIONS

STANDARD DESCRIPTORS AND DESCRIPTIVE CRITERIA FOR DISCONTINUITIES

GEOLOGY NOMENCLATURE COMMITTEE CHECKED CHUCK SULLIVAN
DRAWN MARSHALL MONSON TECH. APPROVAL PETER M. ROHRER
APPROVED MARK McKEOWN (PEER REVIEWER)

CADD SYSTEM	CADD FILENAME	DATE AND TIME PLOTTED
AutoCAD Rel. 16.0 DENVER, COLORADO	40–D–7023.DWG MARCH 8, 2000	JANUARY 27, 2005 10:18

40–D–7023